BBC RD 1974/6

BBC • IBA

Engineering Research Report

The work covered by this report was undertaken by the BBC Research Department for the BBC and the IBA

Computer programs for u.h.f. co–channel interference prediction using a terrain data bank

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THE BRITISH BROADCASTING CORPORATION February 1974

BBC RD 1974/6
UDC 621.391.812.8
681.327.63

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Summary

A set of computer programs has been written to predict the interference caused by co-channel stations to the service of a television transmitter. These programs use geographical and transmitter information stored permanently on a magnetic drum. In this report an outline is given of the methods employed by the programs. Details are given of the required input and the form of output. This report is companion to a report on similar programs used for the prediction of service areas.

Issued under the authority of

P. Rainger

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION
February 1974
(RA-126)

COMPUTER PROGRAMS FOR UHF CO-CHANNEL INTERFERENCE PREDICTIONS USING A TERRAIN DATA BANK

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COMPUTER PROGRAMS FOR UHF CO-CHANNEL INTERFERENCE PREDICTION USING A TERRAIN DATA BANK

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1. Introduction

The network of u.h.f. television stations has reached the stage where small pockets of unserved population are being provided with services from low power relay stations. It is important that the sites, operating channels and specifications of these stations are chosen so that their services are not impaired by interference from established or planned co-channel stations, and that the services of the latter are not degraded by the new stations. Computer programs[1] without a theoretical basis have been used for many years for co-channel interference (c.c.i.) assessments, but it was recognised that detailed terrain information along the whole propagation path could give more accurate results, particularly for short and medium distance paths.

The purpose of this report is to describe computer programs for calculating c.c.i. fields on paths up to 1000 km long for which profiles are obtained from a terrain data bank. This data, a second data bank containing transmitter information together with a list of receiving sites at which the interference is to be assessed, and the programs themselves are held within the Univac 1108 computer system operated by the University Computing Company. The programs are written in Univac 1108 Fortran V.

2. Data banks

2.1. Terrain data bank

The terrain data bank consists of a large number of information 'units', each unit being a representative height and 'clutter' (building and tree) density for a small square. The squares are defined for three grid systems, all drawn up on transverse mercator projections:

1. National grid of Great Britain extended to include the Channel Islands and the Cherbourg Peninsula (map origin 49°N, 2°W)
2. Irish grid (map origin 53·5°N, 8°W)
3. 'Continental' grid for N.W. Europe (map origin 50°N, 0°)

The data squares for grid systems 1 and 2 have side ½ km while the continental data is on a 5 km grid since very detailed information about the terrain around the continental transmitters is not required. The data is held in 'blocks' of 400 units comprising squares of 10 km side for the UK and Eire and squares of 100 km side for the continent. The extent of the terrain data contained in the data bank is shown in Fig. 1. The stylised continental coastline shown in Fig. 1 is held within the programs for the dual purpose of determining the grid system in which any point lies and of locating the coast on paths stretching into the continent beyond the data limits.

The height data itself was compiled by several organisations but the same rules were used to determine the representative height for each unit square. It is sufficient to note that when a square contains a definable feature such as a peak or valley the height of this feature is stored, otherwise the mean height in the square is stored. This scheme tends to emphasise the ruggedness of the terrain but this is offset by the method used to generate the profile (Section 4.2). For the UK and Eire, heights were

TABLE 1

Terrain Data Height Storage Scheme

Height (ft)	Digit Stored	Decoded ht. (ft)	Max. error (ft)
0 (water)	1	0	0
0–1 (land)	2	1	1
2–6	3	4	2
7–18	4	12·5	
19–31	5	25	
32–44	6	37·5	
45–55	7	'	
56–68	8	'	
.	.	'	6·5
.	.	'	
.	.	'	
.	.	'	
.	.	'	
1969–1981	161	1975	
1982–1993	162	1987·5	
1994–2012	163	2000	
2013–2037	164	2025	
2038–2062	165	2050	
.	.	'	
.	.	'	12
.	.	'	
.	.	'	
.	.	'	
.	.	'	
.	.	'	
3963–3987	242	3975	
3988–4024	243	4000	
4025–4074	244	4050	
4075–4124	245	4100	
.	.	.	
.	.	.	
.	.	.	25
.	.	.	
.	.	.	
.	.	.	
.	.	.	
4375–4424	251	4400	

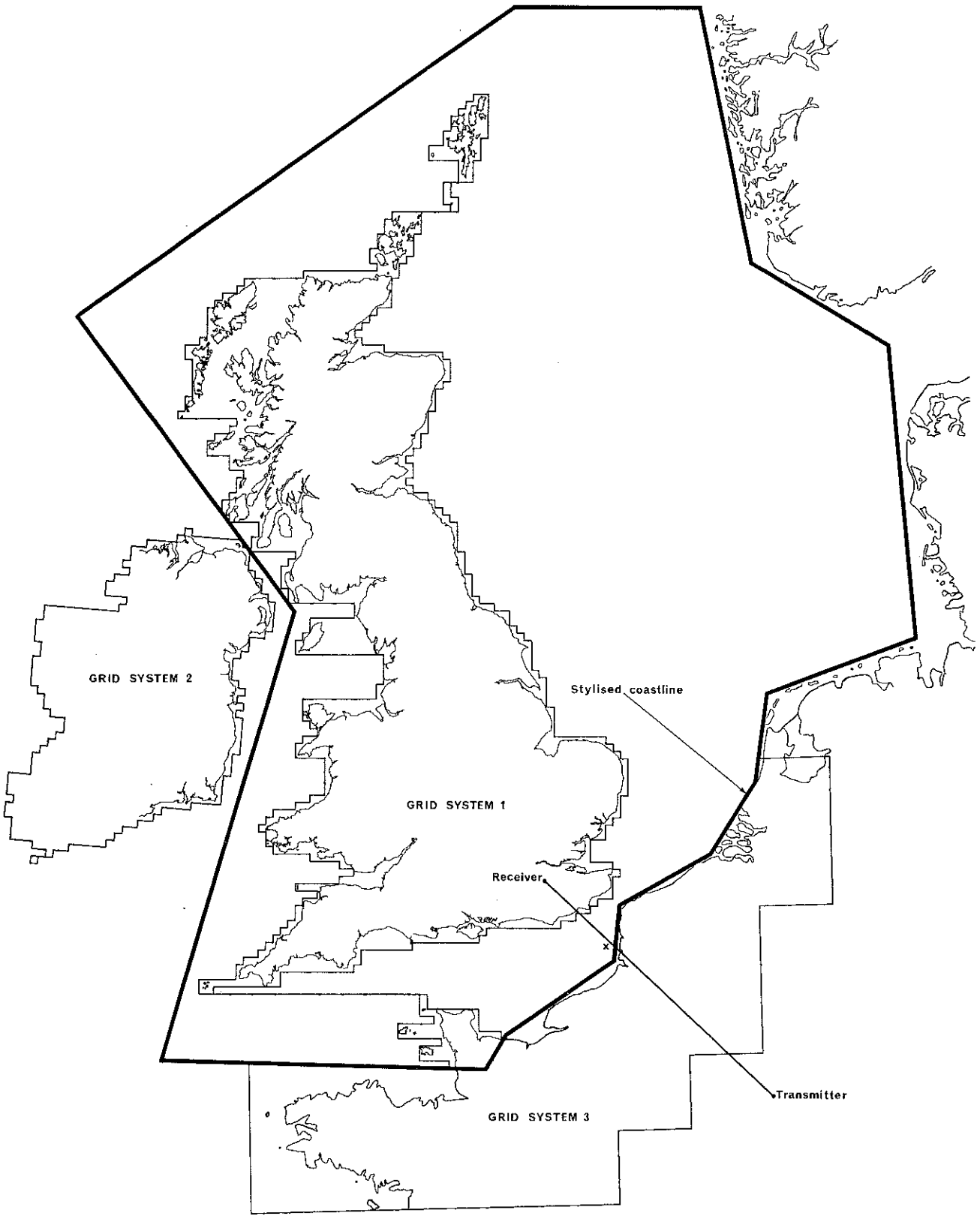

Fig. 1 - The extent of the terrain data bank

obtained from 1:25000 maps and 1 in. : 1 mile where the former were not available. Maps of scale up to 1:250000 were used for the continental data.

Clutter information was obtained for the UK only from 1 in. : 1 mile scale maps. Tree and building densities in each unit square were recorded on a twelve level scale. The occurrence of water was recorded with the tree density information.

It became clear that a total of 1·8 million units each with a height, tree and building density would be too large to handle economically. It was therefore decided to code the heights into 251 levels (8 bits) and reduce the clutter information to one bit – that is YES or NO – to enable four information units to be held in each 36 bit computer word. For economic reasons this clutter information is not used in the field calculation program. The height coding scheme, detailed in Table 1, utilises several features of the data itself and takes advantage of the distribution of population with ground height in the UK.

Maximum height accuracy is required around receiving sites. There are no villages in the UK higher than 1600 ft above mean sea level and therefore lower height accuracy can be tolerated above this figure. About 95% of the stored heights are at multiples of 25 ft and 2% are odd multiples of 12½ ft. The coding scheme reproduces these heights faithfully up to 4000 and 2000 ft respectively. The overall degradation introduced by the coding process is therefore quite small.

The data blocks of 100 words (400 packed units) are stored in rows ordered from south to north through the three grid systems. Each block is held in 4 sectors of a FASTRAND magnetic drum file and access to any block is effected by means of a Fortran function 'BLOCK' which computes the sector address of the first word of the required data block from the easting and northing of the SW corner of the block.

2.2. Transmitter data bank

The transmitter data bank* consists of four randomly accessable FASTRAND data files which are normally accessed with standard Fortran read/write instructions.

1. A Channel register contains the reference numbers of all stations on each channel. This file also contains a directory for the UK relay and continental station data files.

2. The UK main station file contains site, aerial and receiver location information for the UK main stations. The information used within the present programs is detailed in Table 2.

3. The UK relay station file contains identical information to the main station file, but the number of receiver locations is restricted to twenty.

4. The Continental station file is similar, but includes no receivers.

In all the files provision has been made for separate aerial data for each channel, although this is frequently common to all channels. Storage space is also allocated to data used exclusively in other programs.

3. The scope of the programs

We shall now discuss the use of the programs in the planning context and describe several features of the output.

The programs compute the protected field strength from an interfering source at a number of receiver sites associated with the service area of a station. This procedure is controlled by sub-program 'AREA'. The protected field strength (PFS) is that field which must be provided by the wanted station to overcome the interference from the unwanted source and is the sum of the interfering field-strength (FS) and a 'protection ratio' (PR) which depends on the frequency offset characteristics of the two transmitters and the aerial pattern (polarisation and directivity) of the receiving aerial.

Two types of receivers are recognised for c.c.i. purposes: domestic receivers, at height 10 m (32·8 ft) above ground level, and receivers on re-broadcasting links (r.b.l.) which may be at any height. The latter are all located at transmitter sites and their data is accessed from the transmitter data bank. The two receiver types have different stylised aerial directivity patterns for protection ratio calculation. For all receivers the median field strength (FS_{50}) at the aerial is computed together with the field strength exceeded for 5% (FS_5) of the time for domestic sites and that exceeded for 1% (FS_1) of the time for r.b.l. sites. The PFS is calculated for the worst case; thus for a domestic site

$$PFS = \text{MAX}\ (FS_{50} + 10, FS_5) + PR \qquad \text{dB}\,\mu\text{V/m} \quad (1a)$$

and for an r.b.l.

$$PFS = \text{MAX}\ (FS_{50} + 10, FS_1) + PR \qquad \text{dB}\,\mu\text{V/m} \quad (1b)$$

The 10 dB factor added to FS_{50} is an allowance for persistent interference.

A number of operating versions are available, but the two more important are:

1. Specify one station and compute the c.c.i. from or to all stations operating on the channels of the specified station. The two types of prediction are 'forward', i.e. the c.c.i. at the receiver locations of the specified station from all co-channel stations, and 'reverse', i.e. the c.c.i. from the specified station to the receiver locations of the co-channel stations.
2. Specify two stations and compute the c.c.i. from the first to the second on a single channel. More receiver locations can be used in this version and a graphical output may be provided.

* The storage was devised by R.W. Lee.

CALCULATION OF CO-CHANNEL INTERFERENCE FROM A SPECIFIED SOURCE DATE 07 DEC 73

****

CHANNEL 22

	TX NO	NAME	RES	NGR	POL	OFFSET	STATUS	DATE
SERVICE AREA OF	10605	PONTYPRIDD	BBC	ST 85905	V	5	B	170973
INTERFERING SOURCE	10612	ABERTILLERY	BBC	SO224 23	V	5	C	170973

TX-TX DISTANCE 18.2 KM
BEARING 48.6 DEG (U FROM W)

RX NO	NAME	P	NGR	GND HT FT	50% FS (DB MUV/M)	PROT FS (DB MUV/M)		DISTANCE TO TXU (KM)	DISTANCE TO TXW (KM)	DIR OF TXW (DEG EGN)	REL DIR (U-W) (DEG)
51001			ST 20900	587.5	39.0	90.5	M	23.4	6.2	87.5	-28.6
51002			ST 25900	825.0	65.5	117.0	M	22.8	5.7	87.5	-29.0
51003			ST 30900	975.0	74.5	126.0	M	22.4	5.2	87.0	-29.4
51004			ST 35900	900.0	74.5	125.5	M	22.0	4.7	86.5	-29.8
51005			ST 40900	900.0	75.0	126.0	M	21.6	4.2	86.5	-30.2
51006			ST 45900	925.0	75.5	126.0	M	21.2	3.7	86.0	-30.4
51007			ST 50900	725.0	72.5	123.5	M	20.8	3.2	85.5	-30.6
51008			ST 55900	425.0	45.0	96.0	M	20.4	2.7	84.5	-30.6
51009			ST 60900	225.0	29.0	80.0	M	20.0	2.2	83.5	-30.4
51010			ST 65900	225.0	34.0	85.5	M	19.6	1.7	81.5	-29.4
51011			ST 70900	200.0	32.5	85.0	M	19.2	1.2	78.5	-27.2
51012			ST 75900	300.0	23.5	78.0	M	18.8	.7	71.5	-21.0
51013			ST 80900	450.0	23.5	78.5	M	18.4	.3	45.0	4.0
51014			ST 85900	750.0	21.0	60.0	M	18.0	.3	315.0	93.0
51015			ST 20905	500.0	40.5	90.5	M	23.0	6.2	92.0	-32.0
51016			ST 25905	450.0	39.5	89.5	M	22.6	5.7	92.0	-32.8
51017			ST 30905	475.0	37.5	87.0	M	22.2	5.2	92.5	-33.8
51018			ST 35905	525.0	38.5	87.5	M	21.8	4.7	93.0	-34.8
51019			ST 40905	425.0	40.5	89.0	M	21.4	4.2	93.0	-35.8
51020			ST 45905	250.0	20.5	68.5	M	21.0	3.7	93.5	-37.0
51021			ST 50905	250.0	24.5	72.0	M	20.6	3.2	94.0	-38.4
51022			ST 55905	250.0	16.0	63.0	M	20.2	2.7	95.0	-40.0
51023			ST 60905	350.0	18.5	65.0	M	19.8	2.2	96.0	-41.8
51024			ST 65905	525.0	72.0	117.0	M	19.4	1.7	98.0	-44.6
51025			ST 70905	200.0	35.0	78.5	M	19.0	1.2	101.0	-48.6
51026			ST 75905	200.0	24.0	64.0	M	18.6	.7	108.0	-56.6
51027			ST 80905	400.0	26.5	65.5	M	18.2	.3	134.5	-83.8
51028			ST 85905	750.0	28.5	67.5	M	17.8	.3	224.5	-174.6
51029			ST 20910	450.0	27.0	75.5	M	22.8	6.2	96.5	-35.6
51030			ST 25910	300.0	21.0	69.5	M	22.4	5.7	97.0	-36.8
51031			ST 30910	300.0	15.5	63.0	M	22.0	5.2	98.0	-38.0
51032			ST 35910	275.0	18.5	66.0	M	21.6	4.7	98.5	-39.6
51033			ST 40910	250.0	9.0	55.5	M	21.0	4.3	99.5	-41.4
51034			ST 45910	475.0	20.0	65.5	M	20.6	3.8	101.0	-43.4
51035			ST 50910	500.0	28.0	72.5	M	20.2	3.3	102.5	-45.8
51036			ST 55910	425.0	18.5	62.0	M	19.8	2.8	105.0	-48.8
51037			ST 60910	700.0	61.5	103.5	M	19.4	2.3	108.0	-52.8
51038			ST 65910	750.0	76.5	116.0	M	19.0	1.9	113.0	-58.4
51039			ST 70910	350.0	34.0	73.0	M	18.6	1.4	120.5	-67.0
51040			ST 75910	200.0	29.0	68.0	M	18.2	1.0	134.5	-82.0
51041			ST 80910	200.0	26.0	65.0	M	17.8	.7	161.0	-109.2

Fig. 2 - Output from version 2 prediction

(a) listing

UHF CO-CHANNEL INTERFERENCE CALCULATION
SERVICE AREA OF TX NO 10605 CHANNEL 22
INTERFERING TX NO 10612

PROTECTED FIELD DB (μ V/M)

					68 108	78 98 73 75	
					104 92	75 82 59 116	
					74 78	50 118 59 56	
					72 91	66 69 70 70	
75 69	63 66	55 65	72 62	103 116	73 68	65 70	
90 89 90 117	87 87 126 125	89 68 126 126	72 63 123 96	65 117 80 85	78 64 85 78	65 87 78 60	
				113 94 101 83	78 81 102 87	67 61 72 48	54 75 60 65
				80 101 103 97	99 87 96 91	75 64 79 70	59 60 65 59

ST 100880

0 1
SCALE KM

Fig. 2 - Output from version 2 prediction
(*b*) plotted output

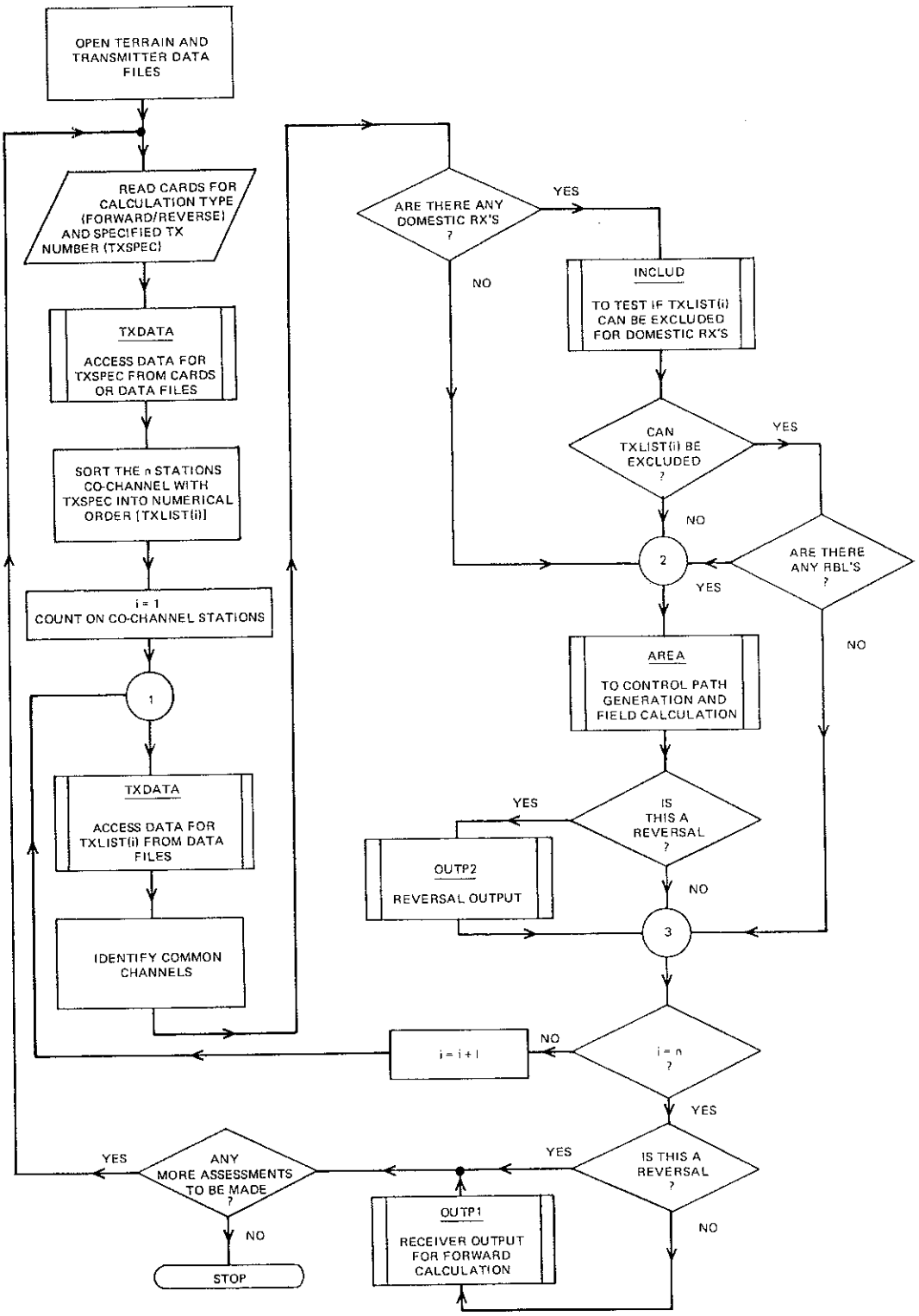

Fig. 3 - Simplified flow chart for version 1 control program

TABLE 2

Transmitter Data

Item	Type	No. of Words	Notes
transmitter number	I	1	
transmitter name	A	3	
responsibility	A		
active deflector indicator	A		
program status	A	1	
tx n.g.r.	—	1	2 letter, 6 figure n.g.r. packed into one word
latitude	F	1	
longitude	F	1	
site height (ft a.m.s.l.)	I	1	
polarisation	A	1	
date of data	A	1	
number of r.b.l.'s	I	1	Total number of receivers: 60 for main stations 20 for relay stations 0 for continental stations
number of domestic receivers	I	1	
r.b.l. numbers	I	1 each	
domestic rx. n.g.r.'s	—	1 each	packed as for tx. n.g.r.
FOR EACH CHANNEL:			
channel number	I	1	
offset ($^1/_3$ line)	I	1	
precision indication	A	1	condition allowed: precision, stabilised, unstabilised
tx. aerial height (ft a.g.l.)	I	1	
rx. aerial height (ft a.g.l.)	I	1	for re-broadcast transmitters
program source	I	1	
max. e.r.p. (kW)	F	1	
aperture (wavelengths)	F	1	
beam tilt (° below horizontal) at 20° intervals	—	6	tilt for three directions packed into each word
h.r.p. (dB below max.) at 10° intervals	A	6	coded figure for six directions packed into each word

I : integer, F : floating point, A : character format

A user may operate the versions in several ways. For example he might run version 1 'forward' on a single channel and find one particular station gives a higher field in the service area of the specified station than he had anticipated. He might then run version 2 with the particular station causing the interference and include more receiver locations. The user might, at this stage, change the parameters of the specified station and re-run. Finally to obtain a complete assessment of the station he would run version 1 on all channels of the specified station in both 'forward' and 'reverse' directions.

Because of its simplicity we shall describe the output of version 2 first. As the example in Fig. 2 shows, this consists of details of the two transmitters, followed by the receiver details: name (for r.b.l.'s), grid reference, FS_{50}, *PFS* and distances and bearings to the transmitters. The 'M' beside the *PFS* value indicates that *PFS* arises from the median field value, rather than the short percentage time value. The accompanying plot (Fig. 2(*b*)) gives the values of *PFS* for the domestic receivers on 1:25000 or 1 in. : 1 mile scale.

A simplified flow chart of the version 1 control program is shown in Fig. 3. The output for this version is somewhat more complicated than that of version 2, consisting of details of the specified station and all co-channel stations, and the details of the field at the receiver locations, as shown in Figs. 4 ('forward') and Fig. 5 ('reversals'). The first part of the output (Fig. 4(*a*) and Fig. 5(*a*)) consists of the specified station name, channels and offsets, status of each channel and date of last data change. This is followed by similar details of the co-channel sources. The column *PR* with each channel gives the protection ratio (dB) on that channel for persistent interference, taking into account offset conditions at the two transmitters. A non shared channel has **** in the *PR* column.

In order to eliminate a large number of unnecessary calculations (from low power distant sources, for example) each transmitter is tested with a procedure to determine whether or not its influence on domestic receivers is likely to be significant.

The 'exclusion procedure' is based on the path

CO-CHANNEL INTERFERENCE PREDICTION FOR STATION 14503 18 OCT 73

****

LONG MOUNTAIN SO265 57 V 58 5 64 -5 61 -5 54 -5 DDDD 170973

98 CO-CHANNEL SOURCES

TX NO	NAME	POL	CHANNEL 1 NO	CHANNEL 1 OFF	CHANNEL 1 P R	CHANNEL 2 NO	CHANNEL 2 OFF	CHANNEL 2 P R	CHANNEL 3 NO	CHANNEL 3 OFF	CHANNEL 3 P R	CHANNEL 4 NO	CHANNEL 4 OFF	CHANNEL 4 P R	STATUS	LAST CHANGE	TX-TX (KM)	PFS @ TXW	EXC PROC
10102	HERTFORD	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	100973	224.5	20.5	2
10110	HENLEY	V	48	-5	****	64	5	40.	67	5	****	54	5	40.	CCCC	100973	195.0	21.8	2
10114	MISSENDEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	100973	194.3	21.1	2
10116	SHERL	V	56	0	****	64	0	40.	62	-5	****	54	0	40.	DDDD	210673	239.2	48.8	1
10122	FOREST ROW	V	48	-5	****	54	-5	55.	62	-5	****	66	-5	****	DDDD	100973	273.7	11.7	2
10202	KIDDERMINSTER	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	AAAC	100973	62.7	79.5	
10336	KENDAL	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	AAAC	280973	187.3	71.3	
10341	CORNHOLME	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	280973	137.1	44.4	2
10407	KEIGHLEY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	AAAC	280973	160.1	79.9	
10408	SHATTON EDGE	V	58	0	40.	52	5	****	48	5	****	54	0	40.	CCCC	280973	119.5	59.7	
10410	RIPPONDEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	230373	137.0	41.3	2
10508	ROSNEATH	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	210673	388.1	31.1	2
10627	CROESERW	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	190973	117.6	40.1	2
10642	MYNYDD BACH	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	190973	113.5	44.4	2
10649	BRECON	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	79.8	62.8	
10653	BLACKMILL	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	123.5	14.6	2
10654	HOPKINSTOWN	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	230373	117.0	13.6	2
10656	PONTARDAWE	V	58	-5	40.	64	5	40.	61	5	40.	68	-5	****	CCCC	210673	115.0	36.8	2
10658	TON PENTRE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	170973	114.2	23.0	2
10704	NEWRY	V	58	-5	40.	64	5	40.	60	-5	****	54	5	40.	CCCC	170973	271.5	22.6	2
10900	PONTOP PIKE	H	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	060473	261.9	55.3	
11000	MENDIP	H	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	290873	159.6	103.4	
11100	WALTHAM	H	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	AAAC	280973	154.9	110.8	
11202	GARTLEY MOOR	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	526.9	46.7	1
11501	WOODBRIDGE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	220573	304.7	47.5	1
11607	HUNMANBY	V	54	5	40.	58	-5	40.	61	5	40.	64	5	40.	DDDD	230373	250.0	38.3	1
12305	PITLOCHRY	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	011073	451.5	16.9	1
12500	MIDHURST	H	61	-5	55.	55	-5	****	58	5	55.	68	-5	****	AAAC	170973	244.0	71.1	
12602	GUERNSEY	H	56	0	****	52	5	****	54	5	40.	48	-5	****	CCCC	011073	355.7	34.9	2
12803	ALDERNEY	V	58	-5	40.	64	5	40.	61	5	40.	68	5	****	DDDD	260473	331.1	42.0	1
12901	PENCARREG	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	92.8	52.5	
12905	PEN CLAWLD	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	210673	141.2	67.3	
13103	HARTLAND	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	260773	206.7	44.6	2
13105	PLYMOUTH	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	260.5	36.7	2
13109	PRINCETOWN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	210673	241.2	35.9	1
13404	SCALLOWAY	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	060473	842.5	6.2	1
13504	LLANLECWYN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	69.3	33.1	2
13712	RUSHEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	260773	193.4	49.2	2
13714	LAXEY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	260773	195.9	44.9	2
13720	PORTPATRICK	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	260773	278.2	33.6	1
13804	ILFRACOMBE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	011073	176.1	51.9	
13900	HEATHFIELD	H	49	0	****	52	-5	****	64	-5	55.	67	-5	****	AAAC	060473	293.7	63.9	
14102	ST JUST	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	170973	330.7	35.0	2
14105	TRURO	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	170973	297.6	31.4	1
14107	NEWQUAY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	210673	282.6	39.7	2
14701	PENICUIK	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	011073	352.9	34.0	2
14702	HADDINGTON	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	210673	368.5	25.6	1
15202	KIRKCONNEL	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	210673	313.2	44.9	2
16106	INNERLEITHEN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	210673	330.8	46.9	1
20208	LETTERKENNY A	H	58	0	40.	61	0	40.	64	0	40.	68	0	****	CCCC	031073	410.8	41.7	2

20215	MONAGHAN	H	54	0 40.	58	0 40.	61	0 40.	64	0 40.	CCCC	031073	312.4	41.0	2
20216	LETTERKENNY B	H	61	0 40.	0	0****	0	0****	0	0****	C	190873	387.8	44.7	2
20301	AACHEN	H	37	8****	58	-8 40.	0	0****	0	0****	AA	150773	663.0	35.1	1
20309	BIEDENKOPF	H	58	8 55.	0	0****	0	0****	0	0****	A	220873	818.9	49.3	2
20326	EBERBACH	H	30	8****	58	0 40.	0	0****	0	0****	AA	220837	919.5	37.6	1
20332	GR FELDBERGTAU	H	34	8****	54	0 40.	0	0****	0	0****	AA	140873	842.8	44.5	1
20335	FREIBURG	H	33	8****	58	8 55.	0	0****	0	0****	AA	140873	913.9	41.9	2
20393	ULM A	H	33	0****	54	-8 55.	0	0****	0	0****	AA	200973			1
20395	WARBURG	H	54	8 40.	0	0****	0	0****	0	0****	C	220873	831.7	41.1	1
20397	WINDBERG	H	58	12 40.	0	0****	0	0****	0	0****	C	011172	713.9	37.8	1
20503	ALENCON	H	48	0****	51	-8****	54	0 40.	0	0****	CAC	200873	503.8	48.2	2
20509	AUTUN	H	48	-8****	51	32****	54	8 40.	0	0****	CAC	200873	807.8	46.3	1
20511	BAR LE DUC	H	48	32****	51	0****	54	-8 55.	0	0****	CCC	200873	737.5	43.5	2
20513	BAYONNE RHONE	H	58	-8 40.	61	8 40.	64	8 40.	0	0****	ACC	200973			1
20537	ONT LEVEQUE	H	58	*** 55.	61	*** 55.	64	*** 55.	0	0****	ACC	10973	436.5	36.0	2
20545	GUERET	H	58	0 40.	61	-8 55.	64	-8 55.	0	0****	CCC	220873	803.0	42.7	2
20546	HIRSON	H	48	0****	51	-8****	54	0 40.	0	0****	ACC	200873	582.1	38.7	2
20547	LA ROCHE YON	H	58	8 55.	61	0 40.	64	0 40.	0	0****	CCC	220873	686.3	45.7	2
20561	MORTEAU	H	48	0****	51	-8****	54	0 40.	0	0****	CCC	210973	935.2	29.9	1
20567	NEUFCHATEL A	H	48	8****	51	0****	54	-8 55.	0	0****	CCC	210973	444.1	60.2	
20580	SARPEGUEMINES	H	58	-8 40.	60	8****	65	8****	0	0****	CCC	210973	830.9	28.1	1
20581	BRIEUC A	H	58	-8 40.	61	8 40.	64	8 40.	0	0****	CCC	220873	462.4	55.1	
20586	STRASBOURG	H	43	0****	56	8****	61	-8 55.	0	0****	CCC	170873	866.8	47.3	2
20591	MANTES	H	58	-32 40.	61	32 40.	64	32 40.	0	0****	CCC	220873	521.7	38.2	2
20595	WISSEMBOURG	H	48	8****	51	8****	54	8 40.	0	0****	ACC	200873	867.8	33.2	1
20610	STADDRESSE	H	48	*******	51	*******	54	*** 55.	66	*******	CCCC	250973	411.9	44.2	1
20619	TOURLAVILLE	H	48	*******	51	*******	54	*** 55.	0	0****	CCC	250973	348.8	31.0	2
20625	TREGUIER	H	58	*** 55.	61	*** 55.	64	*** 55.	0	0****	CCC	230373	427.2	31.4	2
20635	VERNON	H	61	8 40.	64	8 40.	0	0****	0	0****	CC	200973	514.9	39.4	2
20636	S QUENTIN B	H	61	*** 55.	64	*** 55.	0	0****	0	0****	CC	200973	543.0	46.7	1
21009	MARKELO	H	51	-8****	54	-8 55.	0	0****	0	0****	CA	210873	647.2	55.6	
21010	HULSBERG	H	51	8****	54	8 40.	0	0****	0	0****	AA	250973	644.5	49.4	1
21016	EYS	H	51	8****	54	8 40.	0	0****	0	0****	CC	210873	650.9	38.9	1
21109	HOUDENG	H	58	0 40.	61	0 40.	64	0 40.	0	0****	CCC	220873	553.3	43.5	2
21405	SUNDEVED	H	24	-8****	27	8****	61	-8 55.	0	0****	CCC	010873	867.1	57.2	
21407	VEJLE	H	30	0****	33	-8****	64	8 40.	0	0****	CCC	100873	884.2	42.3	1
21503	ARENDAL	H	25	-8****	45	0****	58	-8 40.	0	0****	CCC	030873	984.3	35.4	1
21507	BOKN	H	44	8****	54	8 40.	57	0****	0	0****	CCC	200873	900.6	44.5	1
21514	DRANGEDAL	H	44	8****	54	0 40.	57	0****	0	0****	CCC	250973			1
21515	EIDFJORD	H	45	0****	48	8****	58	8 55.	0	0****	CCC	200873			1
21526	HOVDEFJELL	H	41	-8****	48	-8****	61	-8 55.	0	0****	CCC	170873	995.2	52.1	
21531	JETTA	H	45	-8****	48	0****	58	0 40.	0	0****	CCC	200873			1
21533	KONSMO	H	44	0****	54	0 40.	57	8****	0	0****	CCC	190973	911.1	38.8	1
21534	LESJASKOG	H	51	0****	54	-8 55.	64	8 40.	0	0****	CCC	210873			1
21542	ODDA	H	51	8****	54	-8 55.	64	-8 55.	0	0****	CCC	210873			1

Fig. 4 - Listed output from version 1 'forward' prediction

(*a*) transmitter details

RECEIVING SITES OF LONG MOUNTAIN (14503) CHANNEL GROUP H

	RX NO 895 NGR SJ220115					RX NO 896 NGR SJ220200					RX NO 897 NGR SJ285175				
	GROUND HEIGHT 250.0 FT					GROUND HEIGHT 300.0 FT					GROUND HEIGHT 200.0 FT				
	WANTED TX 7.3 KM @ 144.5 DEG EGN					WANTED TX 15.1 KM @ 163.5 DEG EGN					WANTED TX 12.2 KM @ 190.5 DEG EGN				
INTERFERING TX	50% FS	PFS	DIST	UNW	REL DIR	50% FS	PFS	DIST	UNW	REL DIR	50% FS	PFS	DIST	UNW	REL DIR
KIDDERMINSTER	-1.0	53.0	M58	69.4	-22.0	8.5	57.5	M58	74.4	-35.2	3.5	42.5	M58	67.8	-60.2
KENDAL	-8.5	15.0	M58	182.0	-134.8	-19.5	4.0	M58	173.6	-153.2	-12.0	11.5	M58	175.0	177.8
KEIGHLEY	-7.5	31.0	M58	157.0	-112.4	-11.5	27.0	M58	149.8	-129.4	-7.5	31.0	M58	148.4	-158.8
SHATTON EDGE	-13.0	11.0	58	119.2	-90.6	-11.0	12.5	M58	114.4	-105.8	-11.5	12.0	M58	110.4	-135.6
BRECON	-10.5	33.5	M58	84.6	46.4	-3.0	49.0	M58	92.8	26.6	-7.5	47.0	M58	91.8	4.0
PONTOP PIKE	-3.0	16.5	M58	257.6	-123.8	-8.0	11.5	M58	249.6	-142.0	-1.0	18.5	M58	249.6	-170.4
MENDIP	11.0	42.0	M58	166.2	23.2	18.0	50.0	M58	174.6	5.0	22.5	54.5	M58	171.0	-19.6
WALTHAM	14.5	34.5	M58	158.4	-59.0	24.5	51.0	58	158.0	-74.8	20.5	44.5	58	151.6	-102.6
MIDHURST	1.5	48.5	M61	251.2	-7.0	2.0	48.0	M61	257.6	-24.4	-3.0	34.0	M61	251.6	-50.4
PENCARREG	-9.5	14.0	M58	94.0	78.2	2.0	27.5	M58	100.2	56.0	-7.5	27.0	M58	102.8	32.8
PEN CLAWDD	-16.5	22.0	M58	140.4	94.6	-18.0	20.5	M58	144.8	73.0	-21.5	21.5	M58	149.0	48.4
ILFRACOMBE	-16.5	22.5	M58	179.8	58.4	-9.0	38.0	M58	187.6	38.6	-17.0	37.5	M58	187.8	13.8
HEATHFIELD	-11.0	35.5	M64	300.8	-15.8	-2.5	40.0	M64	306.2	-33.4	-6.5	28.5	M64	299.6	-59.6
NEUFCHATEL A	-17.0	30.5	54	451.2	-10.0	-8.0	36.0	M54	457.2	-28.0	-13.5	22.5	M54	451.0	-54.4
BRIEUC A	-12.5	15.0	M58	468.4	34.4	-4.0	29.0	58	476.8	15.6	-9.0	22.5	M58	474.4	-10.2
MARKELO	-22.0	14.5	M54	651.4	-53.2	-14.0	23.5	54	651.8	-71.2	-20.5	16.5	54	645.2	-98.2
SUNDEVED	-21.5	16.5	61	868.8	-75.8	-18.0	21.0	61	865.8	-94.2	-23.0	21.5	61	860.6	-121.2
HOVDEFJELL	-26.5	16.5	61	993.6	-100.8	-27.5	13.5	61	987.6	-119.2	-25.5	18.0	61	984.8	-146.4

(b)

RECEIVING SITES OF LONG MOUNTAIN (14503) CHANNEL GROUP H

R.B.L. NO 14504 LLANDINAM * QUOTED PARENT TX 14503

N.G.R. SO 50878

GROUND HEIGHT 1490.0 FT

DISTANCE TO WANTED TX 27.9 KM

BEARING OF WANTED TX 50.0 DEG E.G.N.

INTERFERING TX	50% FS DB	PROT FS MUV/M		DIST UNW KM	REL DIR (U-W) DEG
KIDDERMINSTER	22.5	52.5	M58	76.8	50.2
KENDAL	14.5	45.0	58	208.8	-36.6
KEIGHLEY	11.5	74.0	58	186.4	-17.0
SHATTON EDGE	.5	60.0	58	147.4	.4
CROESERW	-22.5	7.0	M58	94.2	141.6
BRECON	19.5	49.5	M58	59.0	129.4
HOPKINSTOWN	-15.0	14.5	M58	97.2	129.6
PONTOP PIKE	17.0	35.5	58	286.2	-27.6
MENDIP	59.0	69.0	M58	147.8	109.6
WALTHAM	51.5	63.5	58	178.8	28.4
MIDHURST	15.0	55.5	61	246.6	81.0
PENCARREG	33.0	48.0	M58	64.8	176.2
PEN CLAWDD	7.5	50.5	58	114.0	164.6
ILFRACOMBE	-3.5	26.0	M58	151.0	150.8
HEATHFIELD	12.5	50.0	64	300.4	73.2
NEUFCHATEL A	2.5	39.5	54	447.4	81.0
BRIEUC A	3.0	38.0	58	445.0	127.0
MARKELO	-3.0	37.5	54	668.4	39.2
SUNDEVED	-5.5	48.0	61	893.6	17.8

Fig. 4 - Listed output from version 1 'forward' prediction

(*b*) conditions at domestic receivers

(*c*) conditions at r.b.l. receivers

CO-CHANNEL INTERFERENCE PREDICTION FOR STATION 14503 18 OCT 73

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***** REVERSALS *****
***** FROM *****

LONG MOUNTAIN SJ265 57 V 58 5 64 -5 61 -5 54 -5 DDDD 170973

9a CO-CHANNEL SOURCES

TX NO	NAME	POL	CHANNEL 1 NO	OFF	P R	CHANNEL 2 NO	OFF	P R	CHANNEL 3 NO	OFF	P R	CHANNEL 4 NO	OFF	P R	STATUS	LAST CHANGE	TX-TX (KM)	PFS @ TXW	EXC PROC
10102	HERTFORD	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	100973	224.5	21.6	2
10110	HENLEY	V	48	-5	****	64	5	40.	67	5	****	54	5	40.	CCCC	100973	195.0	21.7	2
10114	MISSENDEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	100973	194.3	20.7	2
10116	SHERE	V	56	0	****	64	0	40.	62	-5	****	54	0	40.	DDDD	210673	239.2	26.1	2
10122	FOREST ROW	V	48	-5	****	54	-5	55.	62	-5	****	66	-5	****	DDDD	100973	273.7	32.4	2
10202	KIDDERMINSTER	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	AAAC	100973	62.7	72.0	
10306	KENDAL	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	AAAC	280973	187.3	67.9	
10341	CORNHOLME	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	280973	137.1	52.4	
10407	KEIGHLEY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	AAAC	280973	160.1	67.8	
10406	SHATTON EDGE	V	58	0	40.	52	5	****	48	5	****	54	0	40.	CCCC	280973	119.5	55.3	
10410	RIPPONDEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	230373	137.0	56.9	
10506	ROSNEATH	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	210673	388.1	15.1	2
10627	CROESERW	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	190973	117.6	52.4	
10642	MYNYLD BACH	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	190973	113.5	57.8	
10649	BRECON	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	79.8	60.2	
10653	BLACKMILL	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	123.5	31.8	2
10654	HOPKINSTOWN	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	230373	117.0	32.6	2
10656	PONTARDAWE	V	58	-5	40.	64	5	40.	61	5	40.	68	-5	****	CCCC	210673	115.0	37.9	2
10660	TON PENTRE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	170973	114.2	44.6	2
10704	NEWRY	V	58	-5	40.	64	5	40.	60	-5	****	54	5	40.	CCCC	170973	271.5	32.8	2
10900	PONTOP PIKE	H	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	060473	261.9	28.6	2
R.B.L. NO. 10815 REMOVED																			
11000	MENDIP	H	58	0	40.	64	0	40.	61	0	40.	54	0	40.	AAAC	290873	159.6	65.7	
11100	WALTHAM	H	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	AAAC	280973	154.9	51.6	
11202	GARTLEY MOOR	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	526.9	28.1	2
11501	WOODBRIDGE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	220573	304.7	36.7	2
11607	HUNMANBY	V	54	5	40.	58	-5	40.	61	5	40.	64	5	40.	DDDD	230373	250.0	27.6	2
12305	PITLOCHRY	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	011073	451.5	44.9	1
12500	MIDHURST	H	61	-5	55.	55	-5	****	58	5	55.	68	-5	****	AAAC	170973	244.0	41.0	
12602	GUERNSEY	H	56	0	****	52	5	****	54	5	40.	48	-5	****	CCCC	011073	355.7	27.6	2
12603	ALDERNEY	V	58	-5	40.	64	5	40.	61	5	40.	68	5	****	DDDD	260473	331.1	27.3	2
12901	PENCARREG	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	92.8	54.4	
12905	PEN CLAWDD	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	210673	141.2	79.6	
13103	HARTLAND	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	260773	206.7	63.0	
13105	PLYMOUTH	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	170973	260.5	31.9	2
13109	PRINCETOWN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	210673	241.2	26.7	2
13404	SCALLOWAY	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	060473	842.5	16.5	1
13504	LLANDECWYN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	170973	69.3	41.8	2
13712	RUSHEN	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	260773	193.4	59.4	
13714	LAXEY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	260773	195.9	77.9	
13720	PORTPATRICK	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	260773	278.2	27.0	2
13804	ILFRACOMBE	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	011073	176.1	54.1	
13900	HEATHFIELD	H	49	0	****	52	-5	****	64	-5	55.	67	-5	****	AAAC	060473	293.7	32.3	2
14102	ST JUST	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	170973	330.7	48.0	2
14105	TRURO	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	DDDD	170973	297.6	23.5	2
14107	NEWQUAY	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	DDDD	210673	282.6	47.5	2
14701	PENICUIK	V	58	5	55.	64	-5	55.	61	-5	55.	54	-5	55.	CCCC	011073	352.9	31.2	2
14702	HADDINGTON	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	DDDD	210673	368.5	12.7	2
15202	KIRKCONNEL	V	58	0	40.	64	0	40.	61	0	40.	54	0	40.	CCCC	210673	313.2	44.9	2
16108	INNERLEITHEN	V	58	-5	40.	64	5	40.	61	5	40.	54	5	40.	CCCC	210673	330.8	12.4	2

Fig. 5 - Listed output from version 1 'reverse' prediction
(*a*) transmitter details

CO-CHANNEL INTERFERENCE PREDICTION FOR STATION 14503 18 OCT 73

***** REVERSAL *****

	TX NO	NAME	RES	NGR	POL	CHANNEL 1 NO	CHANNEL 1 OFF	CHANNEL 2 NO	CHANNEL 2 OFF	CHANNEL 3 NO	CHANNEL 3 OFF	CHANNEL 4 NO	CHANNEL 4 OFF	STATUS	LAST CHANGE
TO SERVICE AREA OF	11000	MENDIP	BBC	ST563488	H	58	0	64	0	61	0	54	0	AAAC	290873
FROM INTERFERING SOURCE	14503	LONG MOUNTAIN		SJ265 57	V	58	5	64	-5	61	-5	54	-5	DDCC	170973

TX-TX DISTANCE 159.6 KM
BEARING 348.8 DEG (U FROM W)

RX NO	NAME	P	NGR	GND HT FT	50% FS (DB MUV/M)	PROT FS (DB MUV/M)		DISTANCE TO TXU (KM)	DISTANCE TO TXW (KM)	DIR OF TXW (DEG EGN)	REL DIR (U-W) (DEG)
303			ST560160	125.0	-34.0	-2.0	M58	191.6	32.5	.0	-8.8
405			SS965460	50.0	-24.0	-4.0	M58	162.0	59.4	87.5	-77.0
901			ST315585	25.0	-16.0	3.5	M58	146.8	26.4	112.0	114.2
902			SP 25010	350.0	-15.5	9.5	58	129.0	69.9	221.5	102.4
903			ST995705	200.0	-23.5	-3.5	M58	153.2	48.5	243.0	88.4
904			ST870450	375.0	-17.5	2.5	58	171.2	31.0	276.5	62.6
905			ST220245	50.0	-16.0	5.5	M58	180.8	41.5	54.5	-53.2
906			ST465765	50.0	-18.5	1.0	M58	130.4	29.5	161.0	170.2
1443			SU155410	225.0	-26.0	-4.0	M58	186.8	59.7	277.0	54.2
1771			SU235480	350.0	-31.5	-11.0	M58	184.6	67.2	270.0	57.8
11002	BATH	*	ST769654	556.0	5.5	40.5	58	148.8	26.3	231.0	109.2
11003	WESTWOOD	*	ST817597	285.0	-10.0	11.5	58	155.8	27.5	246.5	92.6
11005	CALNE	*	ST996699	340.0	3.0	32.0	58	154.0	48.0	244.0	87.8
11007	KINGS WEST	*	ST547775	315.0	-.5	11.5	58	131.0	28.7	176.5	170.8
11008	ILCHESTER	*	ST577700	160.0	.0	10.0	M58	139.0	21.2	183.5	163.2
11009	WASHFORD	*	ST 57410	120.0	-2.5	10.0	58	165.8	51.0	81.0	-74.0
11012	SWINDON	*	SU149881	400.0	5.5	28.5	58	146.8	70.3	236.0	87.0
11015	MERE	*	ST793291	350.0	-10.0	18.0	58	184.0	30.2	310.5	32.6
11018	STROUD	*	SO836077	725.0	33.5	54.0	58	113.2	64.8	204.5	125.0
11019	CIRENCESTE	*	SP 4057	605.0	2.0	27.0	58	124.0	71.8	217.5	105.8
11020	NAILSWORTH	*	ST845991	410.0	2.0	35.5	58	121.0	57.5	209.0	122.2
11021	CHALFORD	*	SO894020	570.0	5.0	35.5	58	121.0	62.5	211.5	117.0
11022	WARMINSTER	*	ST880430	500.0	1.5	36.0	58	173.6	32.1	280.0	58.8
11023	SHREWTON	*	SU 63434	325.0	-14.5	-1.0	58	180.6	50.1	276.0	57.6
11024	MARLBOROUG	*	SU209688	650.0	-3.0	22.5	58	166.0	67.4	252.5	72.6
11025	UPAVON	*	SU125611	660.0	-3.0	22.5	58	167.8	57.3	257.5	71.6
11026	PORLOCK	*	SS907475	800.0	1.0	27.5	58	162.0	65.3	88.5	-76.0
11027	LYNTON	*	SS748500	975.0	-1.0	10.5	58	163.8	81.2	90.5	-72.4
11028	AVEBURY	*	SU 97682	600.0	3.0	37.0	58	160.4	56.6	250.0	78.8
11029	CERNE ABBA	*	ST645012	767.0	-11.0	22.0	58	207.8	48.2	350.0	-.6
11030	WESTON S M	*	ST340580	400.0	23.0	33.0	M58	147.6	24.0	112.0	115.4
11031	REDLAND	*	ST598751	155.0	-8.5	15.0	58	134.6	26.5	187.5	158.0
11032	BOX	*	ST819689	250.0	-2.0	7.5	M58	147.4	32.4	231.5	106.2
13200	STOCKLAND	*	ST222014	750.0	-4.0	17.0	58	204.0	58.3	35.5	-34.4

Fig. 5 - Listed output from version 1 'reverse' prediction
(*b*) conditions in the service area of one transmitter

between the unwanted and wanted transmitters. There are four tests that the path has to pass before the unwanted transmitter is judged to be of importance. The number of the test at which the exclusion occurs is printed in column EXC/PROC on the listed outputs. The four tests are

1(a) path distance >1000 km (no distance or value for *PFS* is printed)

1(b) protected field strength at the wanted transmitter site <x dB μV/m, assuming the path to be a sea path. This calculation of protected field strength is based on the field strength exceeded for 5% of the time and the protection ratio does not include receiver aerial directivity.

2(a) wanted transmitter in N. Ireland, unwanted transmitter in Continental Europe. The value of *PFS* listed for a a path excluded on this basis is that from 1(b).

2(b) protected field strength at the wanted transmitter site <x dB μV/m, for the path extracted from the terrain data bank. The field strength calculation is for 5% time, and the protection ratio does not include aerial directivity.

The basic value of x is 40 dB μV/m when the wanted transmitter is a high power station with a large service area and 50 dB μV/m for a low power relay station. A further 10 dB is added to this value if the distance between the two transmitters is >200 km.

The exclusion procedure is normally successful in removing about 80% of the interfering sources.

The listing of the conditions at the receiver locations for 'reversals' (i.e. influence of the specified station) shown in Fig. 5(*b*) is similar to that already described for version 2 output with the addition of the number of the channel which produces the highest protected field. The frequency used in the field strength calculation is appropriate to the arithmetic mean of the common channels.

The listing for 'forward' prediction (i.e. the influence on the specified station) is shown in Fig. 4(*b*) and 4(*c*) for domestic and r.b.l. sites respectively. The components of the output which are given for those stations not excluded are compatible with those described above. For r.b.l. sites, the output is not compressed across the page because each transmitter is handled individually for each r.b.l. for exclusion purposes. The exclusion is at 70 dB μV/m for *PFS* at the r.b.l. site, including aerial protection, for the path assumed to be sea. The calculation is for 5% time. The printed list includes only those transmitters not excluded on this basis or on conditions 1(a) or 2(a) as above. (The r.b.l. site replaces the wanted transmitter in the above nomenclature.)

4. The control sub-program (AREA)

The purpose of this sub-program is to control the calculation of protected field strength from an unwanted transmitter at the receiver locations of a wanted transmitter. A simplified flow-chart of its operation is shown in Fig. 6. Much of the sub-program is involved in sorting the unwanted transmitter to receiver paths into categories and controlling terrain data handling and generating path profiles as a series of heights and distances (subroutines TRANAR, SPATH and PATH). The final part of the sub-program controls the field strength calculation (GRIDFS), radiation pattern correction (AECORR), protection ratio calculation (PROTCT) and stores the results prior to printing. The named subroutines will be described later.

It was found to be uneconomic to access each path from the data-bank directly so terrain data is always transferred into core-store in bulk (TRANAR) before the paths are extracted. However the area of core available for this data is limited to about 20,000 words, so that long and short paths are handled in slightly different ways. For unwanted transmitters within 150 km of a group of receivers the data for all the paths can generally be transferred and held in core whilst the profiles are extracted (PATH) and protected fields calculated for each path in turn. For longer paths, controlled by SPATH, only sufficient data for 150 km lengths is held at one time, so each path is built up in 150 km sections (TRANAR and PATH) and the calculations are completed before proceeding to the next path.

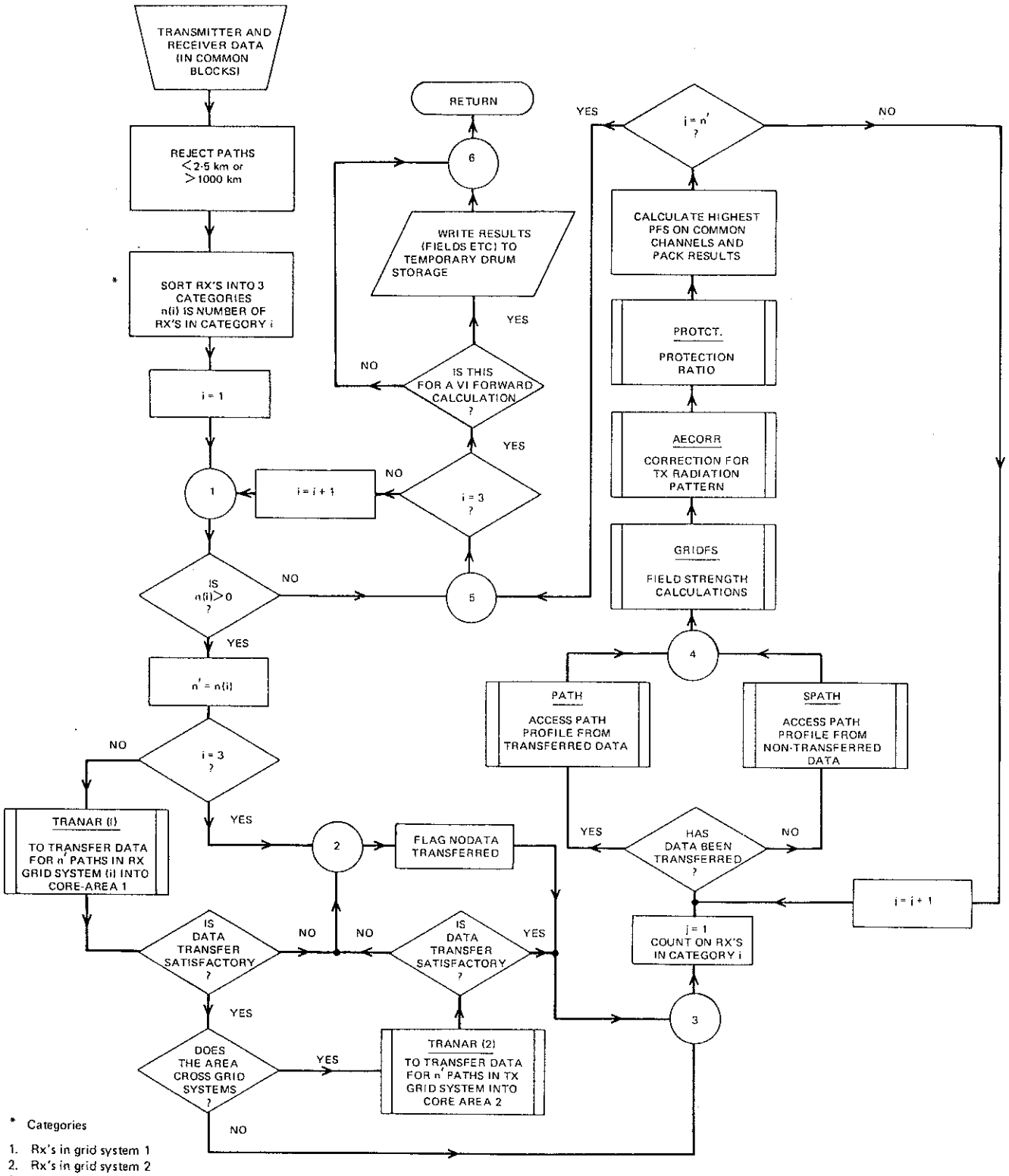
4.1. Transfer of terrain data to core-store (TRANAR)

The procedure is illustrated in Fig. 7. First, the extremities of the area enclosing the receivers are determined and a rectangular box is constructed to enclose the data blocks (10 x 10 km squares for grid systems 1 and 2, 100 x 100 km square for grid system 3) containing the receiver area. The transmitter point is surrounded by a box of side 1 km (10 km for grid system 3) to allow for data interpolation along the path, and the data blocks enclosed are also determined. The data blocks to be transferred to core are determined by the eastings of the intersections of lines AA′ and BB′ with the data rows crossed. A simple directory is then established. This contains the most westerly (IW) and most southerly (IS) grid references of the required data blocks, and for each data row i, a count of the first square in that row IC(i) and its westing ID(i) relative to IW. IC(i) for an extra row beyond the data is also required in order to record the number of squares in the last row. The directory for the data of Fig. 7 shown in Table 3, performs the same function for the transferred data in core as does the function BLOCK for the terrain data bank.

TABLE 3

Directory for the data transferred from drum to core (Fig. 7)

i	IC(i)	ID(i)
1	1	1
2	4	1
3	8	1
4	12	2
5	15	—



* Categories

1. Rx's in grid system 1
2. Rx's in grid system 2
3. Tx outside grid systems or path >150 km (outside 1 or 2)

Fig. 6 - Simplified flow chart for control sub-program AREA

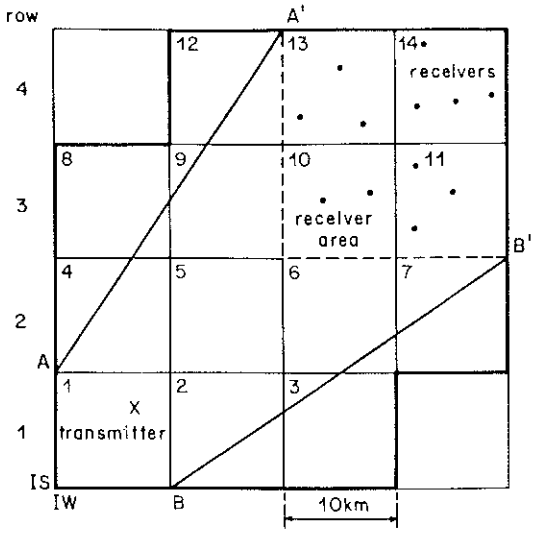


Fig. 7 - To illustrate terrain data transfer to core store

Having determined the data blocks required, the program transfers the data row by row. If a data block is not in the data bank, a dummy block containing 'sea' is inserted into the core data.

A two stage transfer requiring two distinguishable areas of core is necessary when paths cross from one grid system to another.

4.2. Path profile generation (PATH)

A path profile can be interpolated from terrain data in several ways. Methods examined within the present context were

(a) orthogonal projection of the data point on to the path

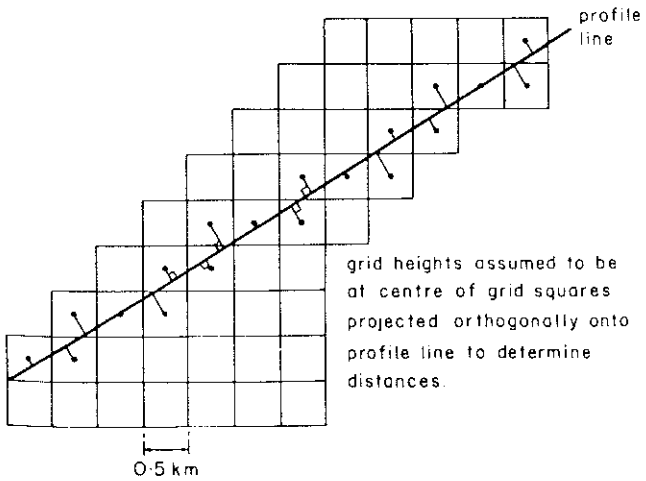


Fig. 8 - Profile generation by orthogonal projection

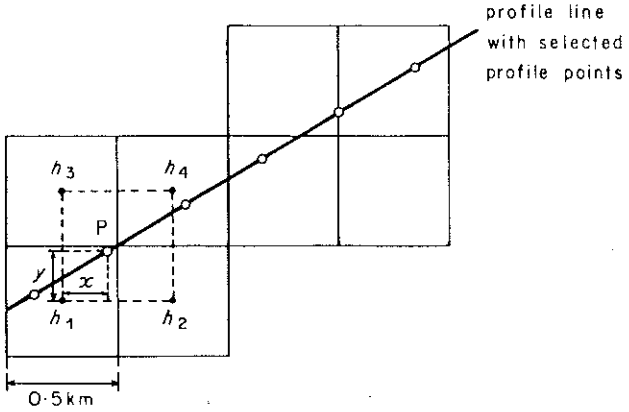


Fig. 9 - Profile generation by square interpolation

(b) 'square' interpolation

(c) row, column and diagonal interpolation[2]

In method (a), illustrated in Fig. 8, the height stored for each data square through which the path passes is projected orthogonally from the centre of the square on to the path. The resulting profile therefore retains the exaggerated ruggedness of the stored data. The profile points have non uniform separations.

Method (b), on the other hand forms a profile with uniform or specifiable separation between the points, and, as illustrated in Fig. 9, linearly interpolates a height from the stored heights for the four data squares surrounding the point. The height at P is given by

$$h = (h_2 - h_1)x + h_1 + [(h_4 - h_3)x + h_3]y - [(h_2 - h_1)x + h_1]y \qquad (2)$$

A surface defined in this way has the appearance of a 'twisted plane' and any section across it parallel to either grid axis is a straight line. As this height is the result of interpolation the profile is somewhat less rugged than that obtained from method (a). Method (c) uses row, column or diagonal interpolation along the profile, according to rules which depend on the angle of the path line with the grid. The method is complicated and can result in different heights for the same point (depending on the interpolation direction) and does not produce a uniform distribution of profile points.

Method (b) was chosen because it 'softens' the data, produces a unique profile and is economic in computing time and program storage.

The profile heights are generated at intervals depending on the distance from the terminals.

Thus,

$$d_{i+1} = d_i + d_{inc}$$

where

$$d_i' > 120 \quad , \quad d_{inc} = 4{\cdot}0$$
$$60 < d_i' < 120 \quad , \quad d_{inc} = 2{\cdot}0$$
$$10 < d_i' < 60 \quad , \quad d_{inc} = 1{\cdot}0$$
$$0 < d_i' < 10 \quad , \quad d_{inc} = 0{\cdot}5$$
$$0 < d_i < 2 \quad , \quad d_{inc} = 0{\cdot}2$$

where d_i is the distance of the ith point from the receiver (km)

d_{i+1} is the distance of the $(i+1)^{th}$ point from the receiver (km)

d_i' is the distance between the ith point and the nearer terminal (km)

d_{inc} is the distance interval (km)

No quantitative comparison between true (map) and data bank profiles has been attempted, but the accuracy is obviously reflected in the comparison between measured and predicted fields described in the Appendix.

Profiles of paths <150 km and each 150 km section of longer paths are generated as arrays of heights and distances in subroutine PATH, together with details of coastal intersections. A stretch of sea is recognised as such if it occupies more than 5 km along the path.

4.3. Paths longer than 150 km or extending beyond the terrain data bank (SPATH)

Profiles for these paths are generated in sections of length 150 km because of limitations of terrain data core-storage. The control splits each path into sections and, using TRANAR and PATH, extracts the profile for each section in turn.

Paths with the transmitter beyond the limits of the data bank have to be handled in a different and less accurate way. These paths are never shorter than about 200 km and generally contain considerable stretches of sea. The procedure used in 'SPATH' is to find the intersection X between the path and the stylised continental coastline shown in Fig. 1. X is then used as a temporary terminal to generate the path profile from the receiver end using 'TRANAR' and 'PATH' in the normal way. The profile is completed by adding points at 20 km intervals from X to the transmitter at the given transmitter ground height.

4.4. Field-strength calculation (GRIDFS)

The philosophy of the field calculation has been described elsewhere.[3] Briefly, it involves computing a path diffraction loss A_D, as a spherical loss A_s (for sea paths) or as an interpolation between a multiple knife-edge loss A_k and a loss calculated over a stylised surface (wedge, A_w or composite cylinder, A_c) for land paths. Except on sea paths for field levels exceeded for 1% and 5% of the time, a loss A_T is computed from the path angular distance. This is to allow for fields resulting from tropospheric irregularities. The basic path loss is the minimum of A_D and A_T with the sea path exceptions above, for which loss is computed on a distance basis. The path loss is completed by adding a 'clutter loss', A_{CL}. A simplified flow chart of subroutine GRIDFS is shown in Fig. 10.

The input data to the subroutine consists of the path profile — heights above mean sea level, distances and coastal intersections and the wavelength. The first operation is to transform the profile heights into a cartesian system, based on a number of effective earth radii. These radii are obtained from the true radius, taken to be 6367 kilometres, by multiplying the latter by a value depending on the percentage time for which the calculation is being made, and on whether the terrain is land or sea. The multipliers used are those obtained in the optimisation process described in the Appendix.

An imaginary string is stretched between the two terminals over the transformed profile to determine which points, called running edges, touch the string. The calculation procedure depends on the number and distribution of these running edges. But first the effect of clutter is assessed by computing the occupancy by buildings and trees within 2 kilometres of the receiver in a zone surrounding the 'string'. This zone is smaller than the first Fresnel zone. The method is based on that given in Reference 4. The density of 0·5 was taken for the land value and 0 when the path crosses over the sea. The height distribution was taken as that given for trees in Reference 4. The constant value of 3 dB is included in the final clutter loss, A_{CL}, except for cases where the coast is within 2 kilometres of the receiver, or the receiver is an r.b.l.

The running edges are tested against three 'grouping' criteria to determine whether or not certain edges are taken as a single crest:

(a) $$d_{i+1} - d_i \leqslant 0{\cdot}5 \text{ km}$$

(b) $$\frac{d_i(D - d_{i+1})}{d_{i+1}(D - d_i)} \geqslant 0{\cdot}9095$$

with D = total path length (km)
and d_i, d_{i+1} are a pair of adjacent running edges (km)

(c) as (a) and (b) above but instead of running edges three points are considered: the receiver horizon, the junction point of transmitter and receiver horizon ray lines, and the transmitter horizon.

If a set of points requires grouping on any of these bases, a virtual edge is formed using the first and last edges of the group.

The procedure now depends on the number of running edges after grouping and a 'flag' which indicates if any of the edges are formed by the sea. The following categories are recognised:

I No edges (line-of-sight)

Here, the subroutine DBMAXK determines the path profile point which gives the maximum Fresnel parameter V (defined in Reference 3). Having found this point three conditions are recognised:

(i) $V \leqslant -0{\cdot}78$: Diffraction loss taken as zero

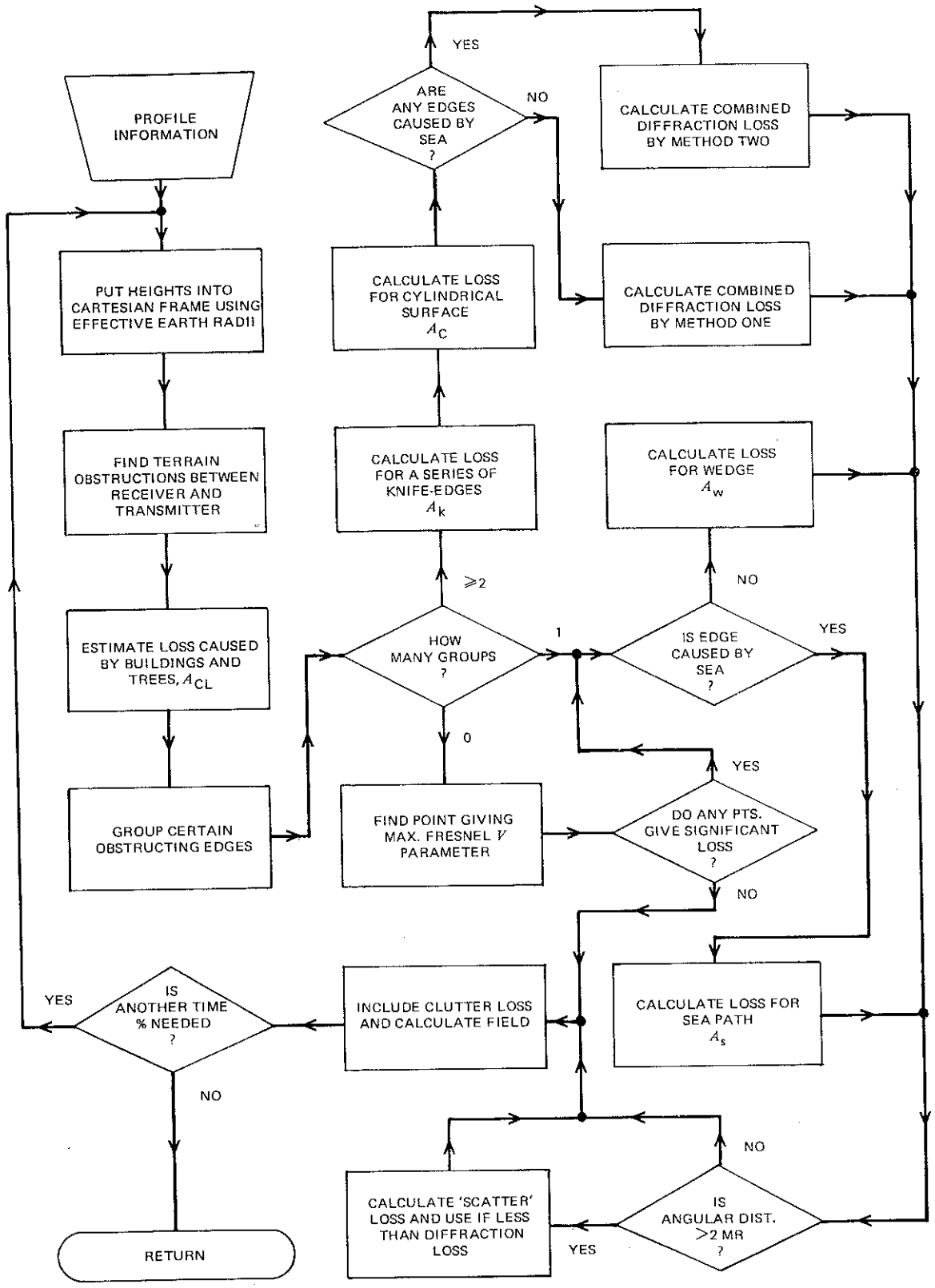


Fig. 10 – Simplified flow chart for GRIDFS

(ii) $V > -0{\cdot}78$ with land forming maximum V point : a wedge loss A_w is calculated. The maximum V point is taken as the wedge apex. The wedge surfaces are defined by the parts of the profile stretching from the terminals to distances short of the apex given by grouping criteria (a) and (b). The surfaces formed touch those points in this profile which produce the maximum internal wedge angle. A restriction is that the wedge surface shall be kept below the aerials by $\sqrt{45d'}$ feet, where d' kilometres is the distance from the particular terminal to the wedge apex. A four-ray approach, explained in the Appendix, is then used to complete the wedge loss calculation.

(iii) $V > -0{\cdot}78$ with sea forming maximum V point : A spherical diffraction formula[3] is used to calculate fields exceeded for 50% of the time. The radius of the sphere is taken to be 8490 km, i.e. $^4/_3$ the physical radius. To obtain fields exceeded for 1% and 5% of the time tropospheric ducts of limited distance are assumed. The loss is taken as:

$$A_s\,(1\%) = \mathrm{MAX}\,(0,\ 94{\cdot}2\ \mathrm{Log}_{10} D - 244)$$
$$A_s\,(5\%) = \mathrm{MAX}\,(0,\ 82\ \mathrm{Log}_{10} D - 179) \qquad (3)$$

This formulation allows free-space propagation for 383 and 153 km respectively.

II One edge

Here, two major conditions are recognised:

(i) edge on land : a wedge calculation is made as in I (ii), except that the wedge surfaces are defined by the parts of the profile short of the *horizons* by the stated amount.

(ii) edge formed by the sea : the loss, A_s depends on the time percentage for which the field is required. To obtain field levels exceeded for 50% of the time, the loss is calculated from a spherical diffraction formula.[3] The levels exceeded for 5% and 1% of the time are determined via Equations (3).

III Two or more edges

A_k is calculated for a series of knife-edges by the method of Reference 3. The profile is then stylised as a surface of four right-circular cylinders forming a single convex surface in which there is no discontinuity of slope. The radii of the inner cylinders are determined by the position of the horizon and the direction of the horizon rays, and the outer cylinders depend on a similar part of the profile to that selected for the wedge stylisation. The cylinders are chosen to pass through profile points which produce the maximum radii, subject to the same restriction that was applied to the wedge surface. The composite cylindrical loss, A_c, is then derived from a method due to Vogler,[5] described in Reference 3. The diffraction loss is computed from:

$$A_D = 0{\cdot}44 A_k + 0{\cdot}38\ \mathrm{MIN}\ (A_c,\ 42\ \mathrm{Log}_{10} D) \qquad (4)$$

if no sea edges flagged, and

$$A_D = 0{\cdot}24 A_k + 0{\cdot}6\ \mathrm{MIN}\ (A_c,\ 42\ \mathrm{Log}_{10} D) \qquad (5)$$

if sea edges are flagged.

For both categories 2 and 3 above, but with the exception of sea path fields exceeded for 5% and 1% of the time, a determination is made of the angle θ between the terminal horizon rays. If this angle exceeds 2 mr a scatter calculation is made using:

$$A_T = \mathrm{MAX}(10 + 37\ \mathrm{Log}_{10}\ \theta_{mr},\ 28 + 10\ \mathrm{Log}_{10}\ \theta_{mr}) \qquad (6)$$

A justification of this form is given in the Appendix.

The final path attenuation relative to free space is given by:

$$A = \mathrm{MIN}\ (A_T, A_D) + A_{CL} \qquad (7)$$

and the field for 1 kW e.r.p. is given by:

$$F = 106{\cdot}9 - 20\ \mathrm{Log}_{10}\ D \quad A \quad \mathrm{dB}\,\mu\mathrm{V/m} \qquad (8)$$

4.5. Radiation pattern correction (AECORR)

Account of the power radiation pattern of the transmitting aerial is taken by linear interpolation in the azimuthal direction between the values of relative radiated power (dB) stored at 10° intervals, and calculating the vertical pattern from a modified sinc function, based on beam tilt and aerial aperture.[1] Finally

$$FS = F + P - H - V \quad \mathrm{dB}\,\mu\mathrm{V/m} \qquad (9)$$

where P is the maximum e.r.p. in dB relative to 1 kW,
H is the loss in dB in the azimuthal plane
V is the loss in dB in the vertical direction

4.6. Protection ratio calculation (PROTCT)

The two components of the protection ratio have already been mentioned. The first component depends on the frequency offset of the two transmitters and the percentage time for which the calculation is being made. 10 dB extra protection is required to overcome persistant interference, compared with that required to overcome that present for a short percentage of the time, quoted in Reference 1.

The receiving aerial protection depends upon the type of receiver (domestic or r.b.l.) being considered. The patterns[1] vary in azimuth only, and are used with the assumption that the receiving aerial is always directed towards the wanted transmitter.

Equation (1) is used to convert field-strength to protected field-strength.

5. Input data

The programs are designed to operate with the minimum of input data at the time of the run. Thus for version 1, for example, it is necessary only to specify the number of the station under consideration, the direction in which the calculation is to be made ('forward' or 'reverse'), and a code to indicate whether the transmitter data is to be accessed from the transmitter data bank or input on further cards. A second code indicates whether or not the receiver data held with the transmitter information is to be supplemented by further card data. Similarly for version 2, both stations may be accessed from the data bank or input from cards, and additional information consists of the channel under consideration and a map scale code if the results are to be presented graphically.

The format of the cards containing transmitter information is identical to that used in setting up and updating the stored transmitter data bank. A set of cards for each station is available. Thus, the effect of a small change, such as the offset condition,[5] of a stored station can be quickly assessed by running the program with the data for the station input from a set of cards including the modification.

6. Conclusions

The programs described in the report enable c.c.i. levels to be predicted in the UK from stations in the British Isles and N.W. Europe with acceptable accuracy and reasonable economy. The use of randomly accessable terrain and transmitter data banks held on a mass storage drum enable predictions to be made very rapidly.

The system is deficient in a number of ways. The true variation of field within ¼ square km can be quite large and the figure quoted may not be truly representative because:

(i) the height stored for the square may not be representative of the heights of the households in the square

(ii) the profile within a short distance of the receiver may not be a faithful representation of the true (map) profile, because of coarseness of the stored data.

To a certain extent these deficiencies can be overcome by examining the relative fields in adjacent squares.

Increased accuracy could undoubtedly by obtained with extremely detailed profile data. This lack of detail made it impossible to calculate losses based upon the curvature of individual hill tops.[3] The requirement for this would be contour heights at 5 m intervals mapped with a horizontal accuracy of better than ±10 m. This requirement is beyond the capability of current maps. Accuracy could also be increased with more clutter data but only at the cost of a considerable increase in data storage and handling charges. This deficiency becomes important when predicting the signals from low power fill-in stations with a small coverage. Thus in these cases calculations are made with the programs described in Reference 4.

The calculation system could be improved if more were known about propagation in the region where the pure diffraction and tropospheric mechanism give roughly equal fields. We do not know to what extent terrain on either side of the profile line can change the field in any given situation. The tropospheric mechanisms used in the program are rather crude, and probably greater accuracy could be achieved by allowing more phenomena, e.g. trapped propagation over low lying land, to contribute to the field.

Nevertheless the field-strength calculation has the philosophical advantage over earlier methods that the calculation method used on any particular path is based on the dominant propagation mechanism on that path, as far as it can be known. The distribution of differences between measurement and prediction indicates that the calculation system is more or less uniformly successful over the wide range of path attenuations encountered in practice.

7. Acknowledgements

The terrain data for most of the UK was commissioned by the Joint Radio Committee of the Nationalised Power Industries. The data for Eire was supplied by Radio Telefis Eirann.

8. References

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Appendix

Minimisation of Differences Between Calculation and Measurement

The system used to calculate attenuation relative to free space has a theoretical basis, but empiricism is also necessary to overcome imperfections in applying the theories. The Appendix outlines the measurement projects used and the processes adopted to develop a calculation system with a small difference from these measurements.

The field prediction program is required to give variations in both time and space, but not for precise times or precise points in space. The time variations required are field levels exceeded for 50, 5 and 1% of the broadcast time, and the primary information required about location is the mean value of the fields at households within areas of ¼ sq. km.

At short distances, where time variability is small, each field value used was the mean of many measurements in the relevant area. Most of the field measurements were made in Guildford and the Potteries. In Guildford the field strength was measured from transmitters at Reigate, Oxford, Guildford (relay), Crystal Palace and a small transmitter with low aerial specially installed on the Crystal Palace mast to compare with the main transmitter. In the Potteries the signals were received from Winter Hill, Sutton Coldfield, Brierley Hill and Fenton. Values also came from measurements taken from the Rowridge transmitter just beyond its service area. The total number of areas of this type was approximately 500.

Evidence on time variability came from experiments conducted by several organisations. Only those paths which were measured for sufficiently long time periods were accepted as evidence. The measurements at these fixed sites were not always typical of the area, so most experimenters obtained site variation factors (S.V.F.) by taking a series of measurements in a district and relating them to a fixed site. It was decided not to use these factors because the areas they represented were poorly defined and were not specific to the present requirement.

If it is assumed the fixed site does not suffer from multipath effects and the ground profile changes are not too abrupt, then the only features liable to produce fields untypical of the surrounding ¼ sq. km are the buildings and trees. For this reason the clutter loss was determined manually using data derived by visits to the sites. Details of the paths used for time variability are given in Tables 4, 5 and 6.

Propagation over sea is substantially different from propagation over land, so paths were categorised with this in mind. This categorisation is aided by imagining a string stretched across the profile from transmitting to receiving aerials. Thus:

(1) String touches only land and no sea stretches in the path exceed 5 km in length.

(2) String touches only land, and sea stretches in path exceed 5 km in length.

(3) String touches land and sea.

(4) String touches only sea.

If none of the profile points is touched by the string but a significant loss is given by terrain below it, the category used is 1 or 2 if the largest intrusion is land and if it is sea category 4 is taken. If no intrusion into the zone by the earth takes place categorisation is irrelevant.

In the tables the first category is labelled 'land', the second and third are labelled 'mixed' and the fourth 'sea'. The categorisation of a path may change if the effective curvature of the earth is changes, a concept covered below.

For all categories and time percentages the calculation of attenuation relative to free space (A in dB) is obtained by:

$$A = A_{CL} + \mathrm{MIN}\,(A_T, A_D) \qquad (10)$$

where A_{CL} = loss caused by clutter (trees and buildings)
A_T = attenuation relative to free space of field received due to irregularities of troposphere
A_D = loss caused by diffraction of earth's surface.

The values obtained depend on the radius assumed for the earth. The time variations are achieved by assigning varying effective radii to the earth. The radius assumed on both land and sea for the mean field level is four thirds the physical radius, but for other time percentages the effective radii are determined empirically.

Prediction of A_{CL} is based on a method described in a companion report[4] on service area prediction. However, in this case several simplifications have been made for economic reasons. The loss is given by:

$$A_{CL} = x_1 + x_2\sqrt{C_g} + x_3 C_g \qquad (11)$$

where

$$C_g = \sum_i \left\{ \sum_j \left[\frac{1}{r_i^2} - \frac{(H_i - y_j)^2}{r_i^4} \right]^{1/2} f(y_j) \right\}^2 \qquad (12)$$

The summation of distance, over i, starts at 55 metres and then from 200 metres to the coast or 2 kilometres (whichever is shorter) in 200 metre steps. r_i is the radius of the volume being considered at the distance in question, with centre at H_i. The summation of height (j) is from the ground or bottom of the volume, (whichever is higher) to the top of the volume in steps of 1 metre. y_j is the height of the strip above ground level. The function 'f' is given by

TABLE 4

UHF EXPERIMENTAL DATA FOR SEA PATHS

TRANSMITTER					RECEIVER				MEAS. F.S.				F.S. MEAS – F.S. CALC		
		Hts. m					Hts. m		dB(μV/m) 1 kW			Clutter Loss			
Name	Location	Site a.s.l.	Ae a.g.l.	Ch. No.	Name	Location	Site a.s.l.	Ae a.g.l.	1%T	5%T	50%T	dB	1%T	5%T	50%T
Caen	48°58′N 0°37′E	345	200	25	Christchurch	SZ198929	18	4	50·5	41	6·5	0	–10	–8	–5
Le Havre	49°30′N 0°11′E	84	105	43	Christchurch				58	45	13*	0	–3	–5	4
Cuxhaven	53°50′N 8°40′E	27	125	24	Whitburn	NZ405609	11	10	29	0*	N.L.	0	0	2	–
Lopik	52°1′N 50°3′E	0	160	40	Aldeburgh	TM464562	2·4	12	47	27	3	3	–9	–13	4
Caradon Hill	SX273707	367	233	28	Torteval	49°30′N 2°40′W	71	9	68	61	27	0	6	–1	–1
Rowridge	SZ447865	137	142	25	Torteval				68	57	19·5	0	5	–4	2
N. Hessary Torr	SX578742	509	209	57	Torteval				–	–	48	0	–	–	+4
Portland	SY692739	148	8	45	Alderney	49°43′N 2°11′W	61	29	71	66	49·5	0	4	–1	0
Stockland	ST222014	229	233	56	Alderney				73·5	68·5	46·5	0	9	4	2
Rowridge	SZ447865	137	142	24	Alderney				73	68	64·5	0	8	3	5
					Alderney			8	69·5	64	43	0	4	–1	4
Scheveningen	52°6′N 4°16′E	13	47	59	Bawdsey	TM341383	5	13	53·5	37·5	–1·5	11	3	–3	4
					Bawdsey			60	62·5	49	11*	0	1	–3	4
					Bawdsey			82	63·5	51·5	13·5*	0	2	0	6
					Manningtree	TM123295	36	10	51·5	36·5	4	4	–5	–7	5
					Manningtree			45	61	49	9·5	0	1	2	6
					Manningtree			75	65	52	9	0	5	5	4
				52†	Bridge of Don	NJ950095	9	9†	19†	N.L.	N.L.	0	–7	–	–
				59	Flambro'	TA247719	46	8·5	50·5	22	–15*	0	–5	–2	0
				32	Flambro'			10	56	29	N.L.	0	0	5	–
				59	Happisburgh	TG376317	15	8·5	68	47	5·5	0	7	–3	1
				32	Happisburgh			9·5	62	41	6·5	0	1	–9	2
				59	Lerwick	HU456394	91	8·5	5*	N.L.	N.L.	0	–5	–	–
				32	Lerwick			9	18	N.L.	N.L.	0	7	–	–
				58	Newton	NU241248	21	8·5	31·5	1*	N.L.	0	–7	–6	–
				32	Newton			9	43	9	N.L.	0	4	2	–
									MEAN				0·6	–1·9	2·7
									STANDARD DEVIATION				5·6	4·8	2·7

† = Av. of two experiments * = Approx. figure N.L. = Noise Level

TABLE 5

UHF EXPERIMENTAL DATA FOR MIXED PATHS

TRANSMITTER					RECEIVER				MEAS. F.S.				F.S. MEAS – F.S. CALC		
		Hts. m					Hts. m		dB(μV/m) 1 kW			Clutter Loss			
Name	Location	Site a.s.l.	Ae a.g.l.	Ch. No.	Name	Location	Site a.s.l.	Ae a.g.l.	1%T	5%T	50%T	dB	1%T	5%T	50%T
Scheveningen	52°6′N 4°16′E	13	47	59	Brookmans Park	TL259049	128	12	13	N.L.	N.L.	7	−2	–	–
					Gt. Baddow	TL729037	46	12	32·5	19	N.L.	2	10	13	–
				32	Feltwell	TL710900	15	9	22	9·5	N.L.	6	1	0	–
					Morborne	TL126913	56	9	28·5	10·5	N.L.	0	4	−1	–
					Pontop Pike	NZ148526	305	9	12	N.L.	N.L.	0	−13	–	–
					Skeffington	SK739035	210	9	30·5	10·5	N.L.	0	5	0	–
					Tacolneston	TM131958	64	9	35·5	22·5	N.L.	16	16	9	–
Lopik	52°1′N 5°3′E	0	160	40	Wickhambrook	TL743578	122	12	19	6·5	N.L.	9	−3	−5	–
Dusseldorf	51°7′N 7°6′E	235	210	29	Wickhambrook				6·5	−10	−29*	9	1	1	−2
					Banbury	SP464389	122	9	−20	N.L.	N.L.	5	12	–	–
					Aldeboro′	TM464562	2·4	12	20·5	2	−19	3	8	3	−3
Dortmund	51°31′N 7°27′E	100	200	27†	Aldeboro′				14†	−1†*	−19†	3	0	0	−3
				29	Wickhambrook	TL743578	122	12	18	−10	−28	9	12	2	0
					Slough	SU996776	18	14	−21	N.L.	N.L.	16	−10	–	–
Cuxhaven	53°50′N 8°39′E	27	99	25	Slough				−12	N.L.	N.L.	16	9	–	–
Huisduinen	52°57′N 4°44′E	17	8	81	W. Beckham	TG141389	91	17	55	32	−5	5	1	−7	0
Crystal Palace	TQ339712	110	198	33	Halwell	SX775517	213	8	18	5	−11	7	1	2	−2
			210	43	Stoke Fleming	SX858483	98	9	3	−3	−21*	7	3	4	−5
Caen	48°58′N 0°37′W	345	200	25	Kingswood	TQ248560	167	9	19	8·5	N.L.	17	0	−8	–
					Mursley	SP824290	158	9	15	6	N.L.	2	−5	−1	–
					Caversham	SU725763	82	12	22·5	13	N.L.	3	−11	−11	–
Le Havre	49°30′N 0°11′E	84	105	43	Caversham				19·5	13*	N.L.	2	−6	−8	–
					Mursley	SP824290	158	9	18	13*	N.L.	2	0	7	–
					Kingswood	TQ247559	167	14	17	8	N.L.	10	−10	−5	–
Rowridge	SZ447865	137	142	27	Heathfield	TQ566220	159	62	55	46	34·5	0	−5	−8	−11
Belowda	SW972626	227	9	71	Widley	SP272142	177	9	14	6·5	−7	0	2	1	1
									MEAN				0·8	−0·6	−2·8
									STANDARD DEVIATION				7·5	6·1	3·6

† = Av. of two experiments * = Approx. figure N.L. = Noise Level

TABLE 6

UHF EXPERIMENTAL DATA FOR LAND PATHS

TRANSMITTER					RECEIVER				MEAS. F.S.				F.S. MEAS – F.S. CALC		
		Hts. m					Hts. m		dB(μV/m) 1 kW			Clutter Loss			
Name	Location	Site a.s.l.	Ae a.g.l.	Ch. No.	Name	Location	Site a.s.l.	Ae a.g.l.	1%T	5%T	50%T	dB	1%T	5%T	50%T
Crystal Palace	TQ339712	110	194	33	Bawdsey	TM341383	5	12	21	7·5	N.L.	23	–6	–13	–
					Caversham	SU725763	79	11	41·5	41	39·5	25	–5	–5	1
					Manningtree	TM123295	27	9	53	42	32·5	10	6	0	0
					Morborne Hill	TL126913	56	9	31	20	7·5	15	–6	–8	–9
					Mursley	SP824290	152	9	50·5	47·5	45	3	–3	–2	0
					Tacolneston	TM131958	64	9	38	23	5	8	2	–1	–7
			198	33	Sunrising Hill	SP345468	98	9	8	2	–6·5	8	–11	–4	–10
					East Harptree	ST550535	293	8	33·5	19	11	8	–4	–9	–10
					Bearley	SP192603	107	9	29	18	2·5	10	4	6	1
					Aldeboro'	TM464562	2·4	11	25	20	5	9	–10	–5	–5
					Banbury	SP464389	122	9	31·5	27·5	18·5	6	–5	–2	–3
			210	43	Oxford	SP513058	55	14	S.P.	S.P.	41·5	0	–	–	4
			199	34	Gt. Baddow	TL729036	37	9	45	44	41·5	14	1	1	1
			211	44	Gt. Baddow				50*	43*	38*	14	5	0	–3
Holme Moss	SE095041	524	181	32	Kingswood	TQ248560	167	9	14	2*	N.L.	16	–8	7	–
					Mursley	SP824290	159	9	47	31·5	11*	3	0	2	–4
					Beddingham	TQ457059	183	9	18·5	–4*	N.L.	0	–3	–9	–
Pontop Pike	NZ148526	305	122	58	Beddingham				7	–5*	N.L.	0	1	3	–
			125	32	Beddingham				5·5	–9*	N.L.	0	–1	–1	–
			122	59	Dishforth	SE377724	34	12	56·5	52	46·5	3	–6	–8	–9
					Slough	SU996776	19	9	–18	N.L.	N.L.	13	–7	–	–
					Moorside Edge	SE071153	338	12	27	18	4·5*	0	1	3	–5
					Dorket Head	SK597472	140	9	18	8	N.L.	10	–6	–6	–
			125	32	Dorket Head				12·5	4	–9	10	–13	1	–3
					Ottringham	TA276241	9	9	31	19	3·5*	9	3	2	–1
					Mursley	SP824290	159	9	21·5	9	4	0	4	6	10
			122	59	Mursley				15·5	5	2*	0	–2	2	8
					Kingswood	TQ248560	167	9	–5*	N.L.	N.L.	16	0	–	–
			125	32	Kingswood				·5	–17*	N.L.	16	5	3	–
Sutton Coldfield	SK113003	169	181	24	Kingswood				17	3*	N.L.	16	–8	–14	–
			183	36	Green Hailey	SP829034	241	9	64	57·5*	45	4	8	8	5
			181	24	Green Hailey				54	47*	42	4	–2	–3	1
					Beddingham	TQ457059	183	9	23	12·5	N.L.	0	–10	–1	–
					Mursley	SP824290	152	9	56·5	51	45	0	4	4	4
				40	Brookmans Park	TL259049	128	12	29	17·5	5	9	–4	–6	–1
					Hatfield	TL215075	71	10	19·5	11	4	9	–5	–9	–1
									MEAN				–2·3	–1·8	–1·4
									STANDARD DEVIATION				5·3	5·7	5·3

* = Approx. figure N.L. = Noise Level S.P. = Short Period

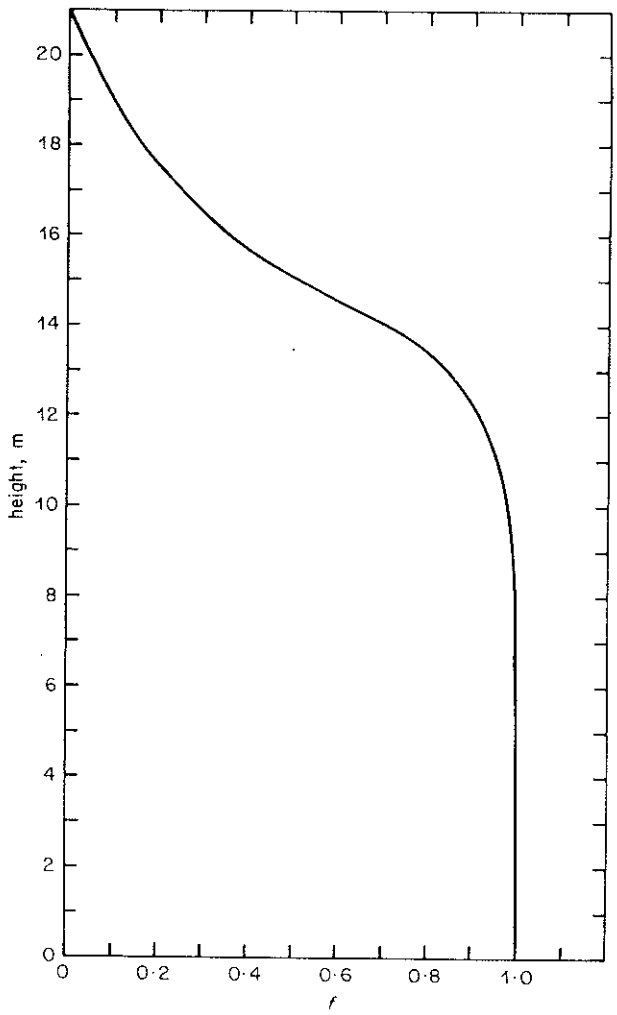

Fig. 11 - Probability, f, of clutter exceeding a given height

Fig. 11. The values x_1, x_2 and x_3 were determined empirically.

The parameter used to calculate A_T is the angle, θ, between the horizon line from the transmitter and the one from the receiver, the functional relationship being determined empirically. The evidence for this work was selected by examining the original field recording charts for the typical fast fading. The selected points are shown in Fig. 12 as median time attenuation relative to free space plotted against log θ_{mr}. Correction was made for clutter losses before the values were plotted on the graph. From this the decision was made to calculate the tropospheric loss as,

$$A_T = \text{MAX}\ (10 + 37 \log \theta_{mr},\ 28 + 10 \log \theta_{mr}) \qquad (13)$$

This gives the lines drawn in Fig. 12.

A_D is calculated for categories 1, 2 and 3 by means of various stylisations of the shape of the terrain profile i.e. knife-edges, wedges and cylinders.

If after the grouping process, described in Section 4.4,

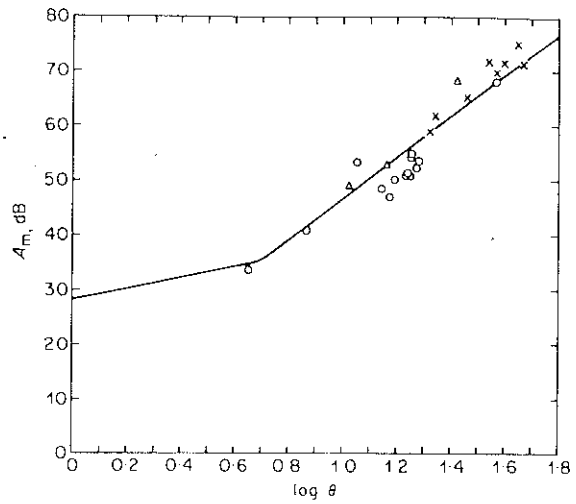

Fig. 12 - Median losses occurring due to tropospheric irregularities for paths categorised into three types
O sea X mixed Δ land

only one edge exists between transmitter and receiver, the wedge stylisation is adopted. The value of A_D is then given by:

$$A_D = -20 \log_{10} \left\{ |F(\nu_1) + R_r F(\nu_2) + R_t F(\nu_3) + R_r R_t F(\nu_4)| \right\} \qquad (14)$$

where
$$F(\nu_i) = \frac{1-j}{2} \int_{\nu_i}^{\infty} e^{j\frac{\pi}{2}(t^2 - \nu_i^2)}\, dt \qquad (15)$$

and the ν_i are the variables associated with the terminals and their images as described in Reference 3. The values of R_r and R_t are simulated reflection coefficients, for each side of the wedge, which are taken as functions of the average differences in height h_t and h_r (feet) between the profile and the assumed wedge. The relationship between the h and R values is taken to be

$$R = \frac{-0{\cdot}99}{1 + x_4 h + x_5 h^2} \qquad (16)$$

where x_4 and x_5 were determined empirically.

If after grouping there remains more than one edge between transmitter and receiver, multiple knife-edge and cylindrical calculations are made and the value of A_D determined by interpolation between the losses given by these two stylisations. Thus:

$$A_D = x_6 A_k + x_7\ \text{MIN}(A_c,\ 42 \log_{10} D) \qquad (17)$$

The term in which D (the path length in km) is used was included because certain data anomolies produced large overestimates of A_c.

In category 4 the value of A_D is calculated directly assuming a simple spherical profile.

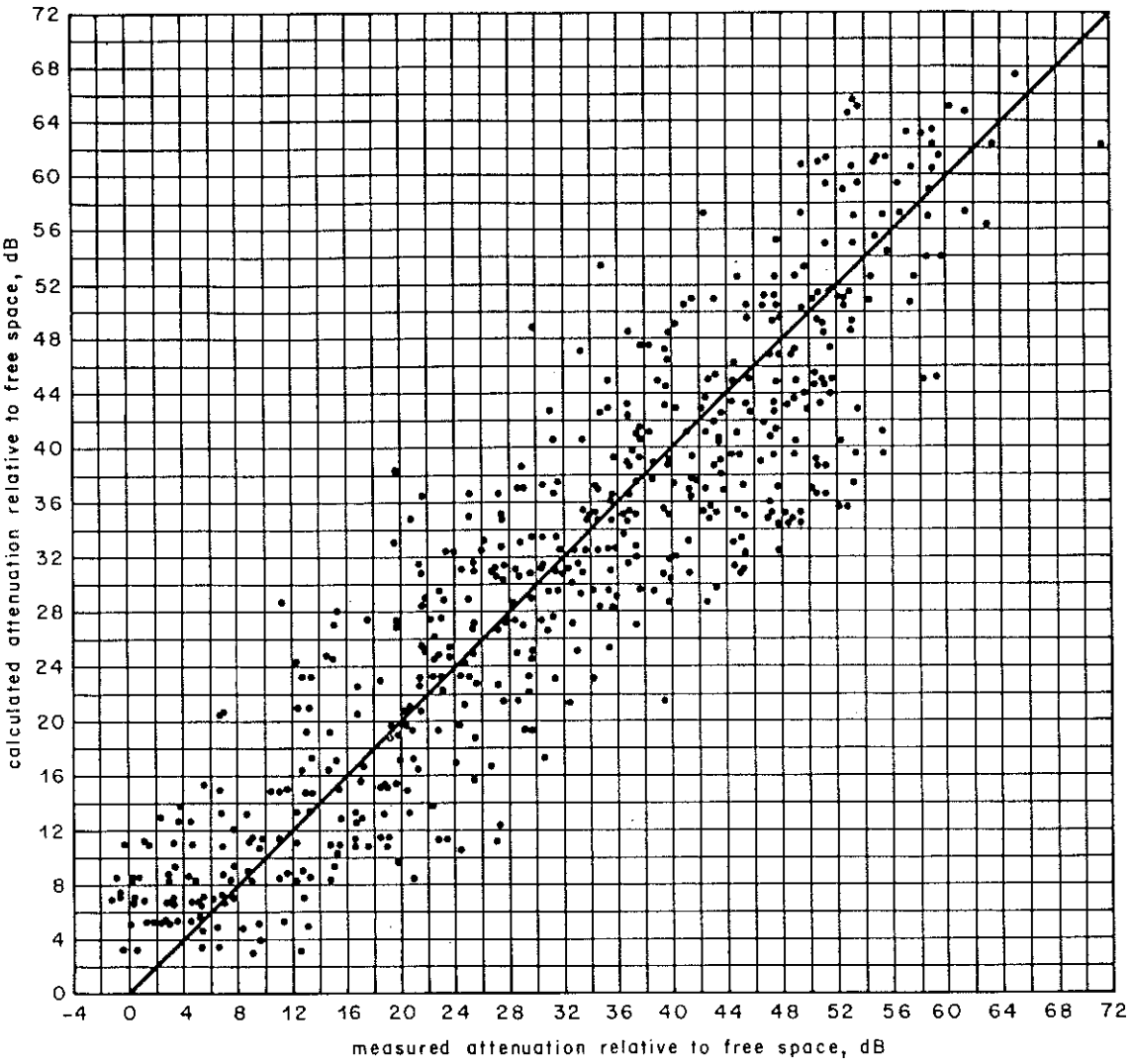

Fig. 13 - Comparison between predicted and measured path attenuations for paths on which small time variation was assumed

Values x_1 to x_7 for categories 1 and 2 were determined in a computer optimisation technique, based on a method by Dickinson,[6] which minimised the sum of the squared difference between calculation and measurement over all cases. Approximately 550 paths were used, with the result that:

$$\left.\begin{aligned} x_1 &= 3{\cdot}0 \\ x_2 &= 5{\cdot}93 \\ x_3 &= -0{\cdot}475 \\ x_4 &= 0{\cdot}0045 \\ x_5 &= 3{\cdot}04 \times 10^{-6} \\ x_6 &= 0{\cdot}44 \\ x_7 &= 0{\cdot}38 \end{aligned}\right\} \qquad (18)$$

These results gave differences between calculation and measurements having a standard deviation of 7 dB with a spread from −18 to 19 dB. These results are plotted in Fig. 13.

In category 3 the path loss is expected to be nearer to the cylindrical value than to the knife-edge result. The empirical evidence for this was that on such paths Equation 17 underestimated A_D to such an extent that diffraction rather than tropospheric scatter became the dominant mechanism. Field charts for these paths showed that the latter mechanism was prevelant, and the anomaly was avoided by replacing x_6 and x_7, for such paths, by:

$$x_6 = 0{\cdot}24 \quad ; \quad x_7 = 0{\cdot}6 \qquad (19)$$

The determination of effective radii for the 5 and 1% time values was carried out in a heuristic manner. The distinction between categories 1 and 2 is necessary because

TABLE 7

Effective Earth Radius Multiplier, k

% time	land	sea
50	1·33	1·33
5	2·2	10·0
1	4·5	25·0

the land and sea sections (in 2) were allowed different effective radii. (The sections join with a common tangent.) The multiplying factors are given in Table 7. The calculation of A is then the same as for 50% time except paths in category 4. Here tropospheric ducts are liable to influence propagation, and the path loss is taken to be of the form given in Reference 1. For 5% time this is:

$$A = A_{CL} + \mathrm{MAX}\{0, (82 \log D - 179)\} \qquad (20)$$

and for 1% time:

$$A = A_{CL} + \mathrm{MAX}\{0, (94{\cdot}2 \log D - 244)\} \qquad (21)$$

In the case of long sea paths it is not reasonable to suppose that the high multiplying factors, given in Table 7,

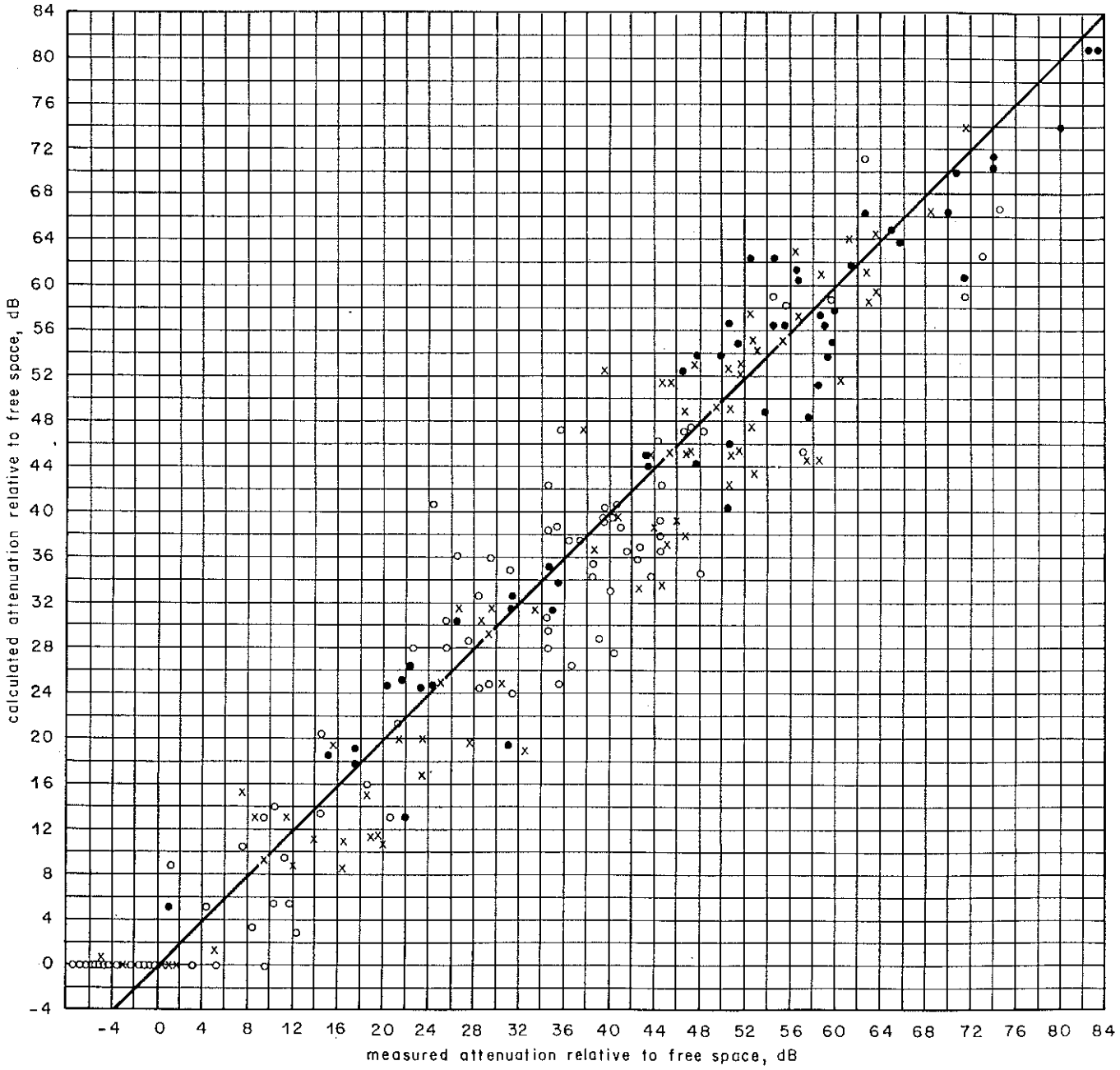

Fig. 14 - Comparison between predicted and measured path attenuations for field levels exceeded for specified time percentages for paths measured over long periods of time

O 1% X 5% ● 50%

are relevant. Thus a reduction is made to these values if the sea sections total more than 153 km on a 5% time calculation, and 383 km on a 1% time calculation. It is assumed that if the sea sections total more than 1000 km the equivalent land multiplying factor is a reasonable estimate. Then for a length between the 153/383 and the 1000 km distances the multiplying factor is determined by interpolation.

The differences between calculation and measurement produced by these techniques are shown in the last three columns of Tables 4, 5 and 6. At the foot of each column is the mean error and the standard deviation. These results are also presented in Fig. 14.

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